Volume 30 MAY, 1946 Number 5

BULLETIN
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CONTENTS

Transformation of Organic Material into Petroleum under Geological Conditions (The Geological Fence) *By Ben B. Cox* 645

Buried Pre-Cambrian Hills in Northeastern Barton County, Central Kansas *By Robert F. Walters* 660

GEOLOGICAL NOTES

Vick Formation of Pre-Tuscaloosa Age of Alabama Coastal Plain *By Louis C. Conant* 711

"Jacob Staff" and Measurements of Stratigraphic Sequences *By J. A. Broggi* 716

Some Developments in Aerial Photography during the War *By L. E. Nugent, Jr.* 725

RESEARCH NOTES

Survey of College Students Majoring in Geology *By A. I. Levorsen* 730

REVIEWS AND NEW PUBLICATIONS

Recent Publications 731

THE ASSOCIATION ROUND TABLE

William Harvey Emmons—Honorary Member *By A. I. Levorsen* 733

Elias Howard Sellards—Honorary Member *By M. G. Cheney* 735

Horace Gardiner Richards—Recipient of President's Award *By Frank R. Clark* 736

Thirty-First Annual Meeting, Chicago, April 1-4, 1946 738

Minutes, Thirty-First Annual Meeting *By Edward A. Koester* 755

Membership Applications Approved for Publication 799

MEMORIAL

The Geologist in World War II—A Memorial *By A. Rodger Denison* 802

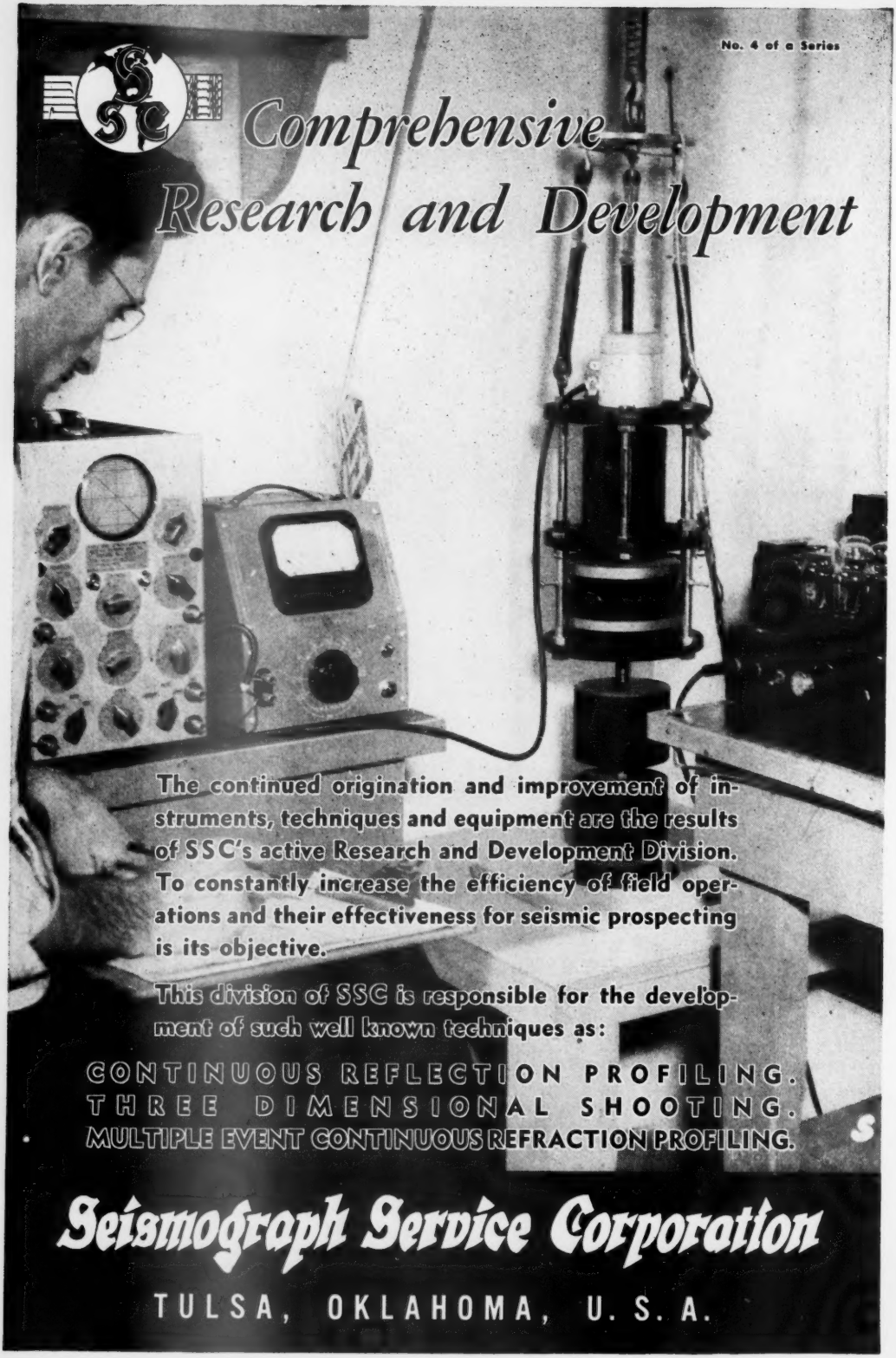
Robert W. Burger *By Rollin Eckis* 803

Kenneth Mason Bravinder *By Gilbert T. Bowen* 805

AT HOME AND ABROAD

Current News and Personal Items of the Profession 807

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of the

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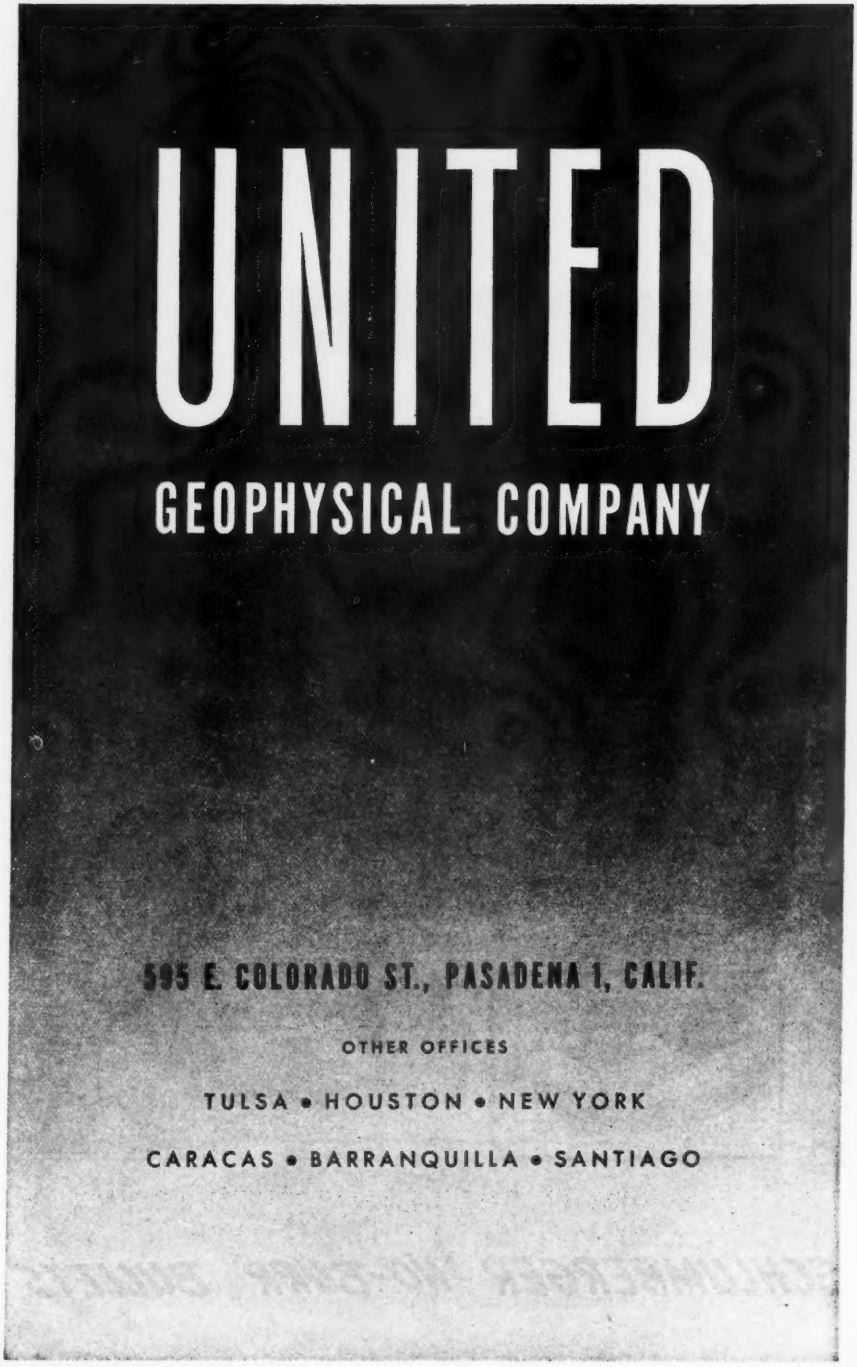
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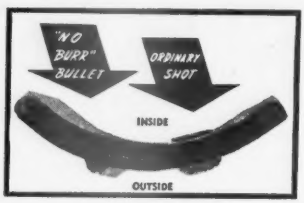
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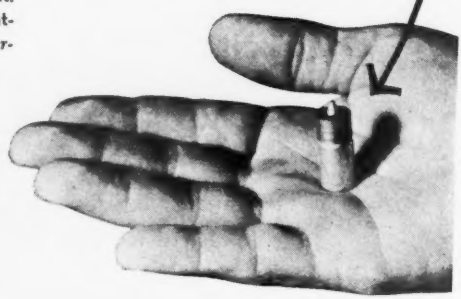
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Baroid Sales Division xxx
Barret, William M., Inc. .....
Bausch and Lomb .....
Burnham, Joe M. xxxviii
Byron Jackson Company .....

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Dowell Incorporated .....

Eastman Oil Well Surveys .....
Economic Geology Publishing Company ..xxiv
Engineering Laboratories, Inc. viii
Exploration Geophysics xlii

Geo. F. Failing Supply Company .....
Fairchild Aerial Surveys .....
Federal Electric Company xxxiv
First Natl. Bank and Trust Co. of Tulsa ...xix
C. H. Frost Gravimetric Surveys xxxviii

General Geophysical Company xxiii
Geophysical Service, Inc. .....Cover iii
Geotechnical Corporation xix
Gravity Meter Exploration Company xli

Haloid Company iii
Heiland Research Corporation xxxix
Hercules Powder Company, Inc. xl
Hughes Tool Company .....Cover iv

Independent Exploration Company xxxvii

Journal of Geology .....
Journal of Paleontology .....
Journal of Sedimentary Petrology .....

Kelly, Geo. F. .....
Keystone Exploration Company xxvii
Koenig Iron Works .....

Lane-Wells Company xxvi
Laughlin-Simmons and Company .....
Lufkin Rule Company .....

Mayes-Bevan Company iv
McCullough Tool Company xxxvi

National Geophysical Company .....
Neuman, Leonard J. xxxv
North American Geophysical Company ...xliv

Petty Geophysical Engineering Company .xxxiii

Reed Roller Bit Company xlviii
Robert H. Ray Co. xxviii
Rogers-Kay, Inc. xxix

Schlumberger Well Surveying Corporation ..vi
Seismic Engineering Company xlv
Seismic Explorations, Inc. xxv
Seismograph Service Corporation .....Cover ii
Society of Exploration Geophysicists .....
Southern Geophysical Company .....
Sperry-Sun Well Surveying Company .....
Sullivan Machinery Company .....

Technical Oil Tool Corporation .....
Thompson Tool Company, Inc. xxii
Triangle Blue Print and Supply Company .xxiv

United Geophysical Company v
Universal Exploration Company xix

Western Geophysical Company xxi

PROFESSIONAL CARDS

California ix
Colorado ix
Illinois .....ix-x
Indiana x
Kansas x
Louisiana x
Mississippi x
New York x
North Carolina xi
Ohio xi
Oklahoma xi
Pennsylvania xi
Texas .....xi, xii, xiii, xiv
West Virginia xiv
Wyoming xiv

GEOLOGICAL AND GEOPHYSICAL SOCIETIES

Appalachian xviii
Ardmore xvi
Corpus Christi xvii
Dallas xvii
East Texas xvii
Exploration Geophysicists xviii
Fort Worth xvii
Houston xvii
Illinois xv
Indiana-Kentucky xv
Kansas xv
Michigan xvi
Mississippi xvi
New Orleans xv
North Texas xvii
Oklahoma City xvi
Rocky Mountain xv
Shawnee xvi
Shreveport xv
Southeastern xv
South Louisiana xv
South Texas xvii
Tulsa xvi
West Texas xvii
Wyoming xviii

Articles for June *Bulletin*

Annual Reviews of Exploration and Development in 1945

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Volume 30 Number 5

BULLETIN
of the
AMERICAN ASSOCIATION OF
PETROLEUM GEOLOGISTS

MAY, 1946

TRANSFORMATION OF ORGANIC MATERIAL INTO PETROLEUM UNDER GEOLOGICAL CONDITIONS[1]

("THE GEOLOGICAL FENCE")

BEN B. COX[2]
Pittsburgh, Pennsylvania

ABSTRACT

This outline lists observations which are being used to guide a geologically coordinated laboratory study on the transformation of organic material into petroleum, by chemists, biologists, physicists, and geologists. The effect of the movement of fluids and gases through sediments on the alteration of petroleum and its possible bearing on the origin of petroleum are omitted from this outline because of the broad nature of this subject. Migration will have to be considered in future studies after basic conditions and processes of transformation of organic material into petroleum have been proved. Limiting conditions are confined to: marine organic origin of petroleum, temperature and pressure limits, and time. An evaluation of present knowledge, with some suggestions for future studies in chemistry, physics, and biology under conditions simulating geologic history, are given.

The recognition of source beds of petroleum is essential to the evaluation and successful prospecting of many great areas throughout the world where some of the conditions common to oil-yielding areas are known to be present but where thus far little or no oil has been discovered. This includes areas where there are important oil fields in restricted parts of a great sedimentary basin but where prospects for petroleum in much larger parts of this same basin are undetermined. Laboratory studies might be directed toward explaining whether there is a fundamental reason for this connected with the original nature of the organic material,

[1] Manuscript received, January 4, 1946.
These observations were originally prepared to stimulate a group of research workers in physics, chemistry, and biology to work with geologists on studies on the transformation of organic material into petroleum as a step toward the recognition of source beds. It led to the inauguration of America Petroleum Institute's Fundamental Research Project No. 43. The observations have been widely criticized by geologists, and the present article may be considered as current geological opinion on the subject. The compiler is indebted to the hundreds of geologists who have contributed and especially E. J. Cox, W. E. Hanson, K. C. Heald, H. W. Patnode, W. P. Rand, and P. D. Trask for help and criticism in the preparation of the manuscript, and to Paul D. Foote, executive vice-president of the Gulf Research & Development Company, Pittsburgh, Pennsylvania, for permission to publish.

[2] Gulf Research & Development Company.

the environment of deposition, and the history of accumulation or alteration which took place during and after burial. If no reason can be found, then the industry must continue to explore these apparently unpromising areas. If criteria for the recognition of source beds are to be established, then a coordinated attack within the limits of geologic history must be made by all the fields of science involved—chemistry, physics, biology, and geology.

A few observations bearing on the problem are briefly noted. Although some of these observations may be proved irrelevant, five because of multiple occurrence (24) are considered irrefutable and are dubbed "posts" in the "geological fence." It may be desirable to do some browsing in the range outside the fence as the grass may look greener there, but safety lies within the "corral." The herd of facts and data must be brought within the corral. Additional observations and others which might be added are considered as "stakes" in the fence. They may be broken and discarded and new stakes supplied, provided they fit conditions of observed geologic history.

The "posts" are: organic origin, marine environment, temperature, pressure, time.

ORGANIC ORIGIN

Most geologists believe that petroleum is of organic origin because it is closely associated with sediments containing relatively high content of organic matter (25). Nitrogenous compounds, optical activity, and chlorophyll derivatives have also been advanced as evidence of organic origin but these conceivably could have been picked up by petroleum migrating through rocks containing such substances. Petroleum-like products can be formed in the laboratory from inorganic substances, but the natural occurrence and distribution of such substances do not fit geological history. Products so formed are inert optically, and do not contain chlorophyll derivatives or nitrogenous compounds.

Equally important is the absence of oil fields where all essentials, except source, are present. The requirements for oil fields are: (a) source, (b) porous reservoir, and (c) trap that will stop upward movement of oil. The second and third requirements can be found in association with rocks of all types—granites, lavas, sediments that accumulated under desert conditions, on the flood plains of rivers and in the sea. No oil pools have been found in such traps and reservoirs in sections devoid of or lean in organic matter, and this has not been due to lack of search.

MARINE ENVIRONMENT

Ninety-nine per cent of the world's oil fields are associated with marine sediments. Known producing formations are limited to certain associations with certain types of marine sedimentary rocks (8). Rocks deposited in fresh water, nonmarine basins, not different in lithologic character from marine rocks which yield petroleum, contain no petroleum. Multiple occurrence of reservoirs and their associated fine-grained marine sediments containing organic matter appear

to be significant. In about one per cent of known petroleum occurrence non-marine sections yield petroleum but the sediments were deposited in brackish water. No crude oil has been found in a sedimentary basin containing only fresh water, terrestrial sediments. Many geologists believe that sediments deposited in enclosed, or partly enclosed, shallow, marine basins yield more petroleum than sediments deposited in more open parts of epi-continental seas.

Trask compared the organic content of many recent marine sediments (40) with that of ancient marine sediments (39), the latter likewise based on thousands of samples (41). The average organic content of recent marine sediments near shore is approximately 2.5 per cent, of ancient marine sediments 1.5 per cent (38—p. 149). Ninety per cent of the samples analyzed had less than 4 per cent. These averages, however, are greatly exceeded in local geographic areas and in limited parts of the stratigraphic section. Organic content of more than 8 to 10 per cent has been reported from ancient rocks in some cases. Many geologists believe that the high organic content in marine rocks may be important in oil origin, but Trask did not find any statistical relationship between quantity of organic matter and the occurrence of petroleum (41—pp. 61–64, 392–402). There is ample residual solid organic material, if it could be converted into petroleum, to account for far more petroleum than is known in the world.

Analyses of solvent extracts of four recent marine sediments were made by Trask and his associates (40—p. 173). These studies indicate that liquid petroleum probably does not occur in sediments at the time of their deposition although small quantities of solid paraffins are found. Trask (40—pp. 173–175; 42—p. 1461) concluded that if any liquid petroleum is present in recent marine sediments, it is less than one per cent of the organic content. ZoBell (59—p. 111) reports finding 10 to 20 milligrams of liquid hydrocarbons in 100-gram samples of fresh recent marine sediments; if we assume an average organic content in these sediments of 2.5 per cent, the liquid hydrocarbons detected would amount to only 0.4 to 0.8 per cent of the organic content of the sediment. Much of the oil detected in ZoBell's studies disappeared after a few days' storage at room temperature, ostensibly due to bacterial activity.

Fatty and oily substances constitute less than one per cent of the organic content of the four organic-rich marine sediments which Trask studied. He considered that this was not enough to account for all of the known petroleum. Fatty acids ranging from cerotic ($C_{26}H_{52}O_2$) to melissic ($C_{30}H_{60}O_2$) constitute 0.002 to 0.006 per cent of the sediment. Organic sulphur compounds form about 0.03 per cent of the deposits. Free sulphur is a common minor constituent of all sediments and ranges from 0.02 to 0.1 per cent (42). Trask's studies did not completely exhaust the possibilities of water-soluble organic matter.

Organic material present in recent marine sediments also includes carbon-hydrogen-oxygen compounds such as cellulose, as well as haemoglobin and chlorophyll and their derivatives (39). Lignin occurs but geologists do not believe that oil was derived from lignin for the same reason they do not believe it was

derived from torbanite and the like. Most simple carbohydrates and proteins are readily decomposed by bacteria soon after reaching the sea bottom (53—p. 421).

Geologists do not believe that non-marine, pyrobituminous substances such as oil shale, tasmanite, torbanite, and boghead coal are a source of crude petroleum. Many sedimentary basins which yield petroleum are devoid of such rocks. Oil fields have not been found in non-marine basins where high concentrations of such pyrobituminous substances occur.

Torbanitic deposits have a matrix of partly decayed plant debris, probably ulmic or humic in nature, with variable amounts of unaltered algal cups, cuticles, cuticular secretions, resins, and oily spores, and pollen exines (1; 4; 18—p. 78; 20; 29—pp. 271, 272; 34; 36; 37; 68).

The oil fractions which can be retorted from such rocks are derived chiefly from oily or resinous materials which were formed during the life cycle of the plant (46—p. 10). Lesser amounts of hydrocarbon products result from the pyrolysis of the matrix. Pond algae for instance, which convert starch to terpenes in their life processes, are preserved in torbanites unaltered throughout geologic time under overburden pressures as great as those which have prevailed in petroliferous areas. These algae and spores are exceedingly resistant to bacterial alteration (1). Laboratory pilot-plant attempts to liberate the oil from torbanitic deposits by pressures far greater than pressures commonly occurring in petroliferous basins have failed (23).

A single living alga before cell division and before the oil formed is absorbed by its cup will release a small drop under moderate pressure (1).

Most oil-field reservoir rocks are hydrophilic. The interstitial water which coats the pore walls commonly has high chloride content which in some cases is much higher than in sea water. This is also true of the bottom and edge waters of most oil fields. Occurrences of relatively fresh interstitial and edge water are believed by the geologists to be exceptions caused by either: migration of meteoric water into the reservoir at the outcrop, resulting in dilution as in the case of the Kern River oil field, California; or migration of oil into sands already saturated with meteoric water (7).

TEMPERATURE

In rare cases, temperatures slightly higher than the boiling point of water occur in petroliferous basins. Temperature of at least 113°C. (235°F.) has been recorded. This is a salt-dome temperature where the salt mass may be acting as a conduit for higher, deeper-seated temperatures. Geologic history, however, indicates that most oil-basin temperatures have been low throughout geologic time. The maximum temperatures have probably been approximately 100°C. for most oil basins. The presence of chlorophyll derivatives in petroleum indicates that a maximum temperature has been less than 200°C. Geologic history does not permit the temperatures required under hypotheses of Engler and his followers (12—p. 1816; 13—p. 592; 14—p. 2365; 16—p. 153).

Geologic observation suggests that the critical original thickness of sediment in which petroleum has been formed is a vertical section of about 5,000 feet. If the average temperature gradient was 1°C. per 100 feet (43) and the average surface temperature 15°C., the minimum temperature under which petroleum could have been formed would have been 65°C. (149°F.). This could have been increased by heat due to exothermic chemical or biochemical reaction or possibly to shear pressures generating heat in fine-grained sediments. Shear-pressure experiments of Hawley (22—pp. 340, 363) and Rand did not raise temperatures. Their samples, however, were air-dried so that they did not completely simulate geologic history.

Temperatures in oil fields are commonly but not always higher than temperatures in adjacent synclinal areas after correction for depth, possibly suggesting some type of exothermic reaction.

PRESSURE

Since some petroleum occurs in basins which have had a stratigraphic thickness of about 5,000 feet but not much more than 5,000 feet, minimum pressures are limited. The hydrostatic head in such a thickness of rock at the deepest part of the basin would not greatly exceed 2,000 pounds per square inch but this pressure probably was exceeded in fine-grained or colloidal sediments at point contacts by the weight of overburden sediment or by shear pressures. Overburden pressure of 5,000 feet would be approximately 5,000 p.s.i. (51—p. 42). However, shear pressure would exceed this by an unknown amount.

TIME

Petroleum occurs in rocks of all ages from the Cambrian to the Pliocene inclusive, but no evidence has been found to prove that any petroleum has been formed since the Pliocene, although sedimentation patterns and thicknesses in Pleistocene and Recent sediments are similar to those in the Pliocene where petroleum has formed. Residual carbon (6) and gas (5) which may have been derived from petroleum occur in metasedimentary pre-Cambrian rocks. The scale factor for time since the Pliocene cannot be reckoned accurately in calendar years but may be taken for scale purposes as about a million years for the formation of the youngest known petroleum in geologic history. Time since the Cambrian can be taken as one billion years (33—p. 79). The apparent absence of formation of petroleum subsequent to the Pliocene must be explained in any study of the transformation of organic material into petroleum.

The foregoing are the bounding "corner posts." The remaining observations should be considered as "stakes" which may or may not be controlling factors in the transformation of organic material into petroleum: radioactivity, bacteria, and catalysts.

RADIOACTIVITY

Radioactive substances are present universally in near surface and subsurface rocks and waters, but concentrations vary. From the measurements made on sea water and deep-sea sediments, it is inferred that thorium and ionium are precipitated in the region of slightly basic conditions near shore (47—p. 11). Algae and plankton differentially retain radioactive substances (47—p. 13). Fine-grained sediments, which contain a greater abundance of organic material than other sediments, are generally higher in radioactivity; as was pointed out previously, however, high organic content in sediments has not been correlated with oil occurrence. Radon occurs in some petroleum gas (35—p. 933) and radium occurs rarely in some petroleum but, like nitrogenous compounds and chlorophyll derivatives, could have been picked up during migration (32). It is probable that radium is commonly present in oil-field waters and where sulphate and carbonate are absent, there appear to be concentrations 2,000 times that of sea water (2).

In the laboratory it has been demonstrated that organic substances may be altered by radioactive emanations. Lind (26—p. 40; 27; 28) converted hydrocarbon gases into more oily substances by bombardment and this has been confirmed by A.P.I. Project 43C. A.P.I. Project 43C also has converted organic sedimentary material into oily matter. The resulting oily material has not been fully identified.

The release of free hydrogen is a by-product of radioactive alteration of hydrocarbons and other organic material. Free hydrogen, however, has not been found in oil fields or in sedimentary rocks. Like the laboratory generation of oils from organic substances by pyrolysis, radioactive bombardment yields large quantities of substances that are not common to petroleum. If radioactivity is a factor in the formation of petroleum, such laboratory bombardment products should be identifiable in the sediments.

BACTERIA

Bacteria, both aerobic and anaerobic, occur indigenously in the soil, in the sea and in sea-bottom sediments. At the surface of the bottom sediments under the sea the concentration of both aerobes and anaerobes is high although bacterial deserts have been reported in certain places. Aerobes are confined to the upper few inches but anaerobes occur to at least 20 feet depth (54—p. 129). The population of anaerobes and consequently their activity, however, decrease rapidly from the surface of the sea bottom to almost zero at a depth of about 25 feet. Bacteria have been found in oil-field waters and in oil-field brines but in most, if not all, cases apparently could be due to surface contamination. In some specially handled well samples from 849 feet and from 3,200 feet in California ZoBell found no bacteria (55—p. 2). At oil-water contacts at similar and greater depths in newly drilled wells he has reported forms identified as bacteria which are different from any previously known forms. An abundance of bacteria, mostly unlike soil or surface species, was isolated from brine at 7,000 feet in an Apex Oil Com-

pany well at El Segundo, California (60—p. 6). In samples of sulphur-bearing limestone and anhydrite from Grand Ecaille, Louisiana, supplied by the Freeport Sulphur Company, ZoBell found a new species of bacteria active in salinity of 160,000 parts per million (56—p. 3). Samples taken from the newly dug shaft of the oil mine near Franklin, Pennsylvania, on the other hand, showed no bacteria (61—p. 5). Bradford, Pennsylvania, reservoir fluids are almost free from sulphate-reducing bacteria and they are also low in sulphide (61—p. 5). Considerable question still remains as to whether or not bacteria and their enzymes during geologic time occurred indigenously and were active below the upper few feet of the sedimentary surface.

That bacteria can alter organic material is proved. Their liberation of oxygen, nitrogen, phosphorus, and sulphur from organic material leaves a residue which can be in the direction of hydrocarbons. Bacteria, chiefly anaerobic bacteria, under controlled laboratory conditions can create reducing conditions which favor the formation and preservation of petroleum hydrocarbons. ZoBell (65—p. 366; 66—pp. 2 and 3) believes that the quantities of hydrogen produced by bacteria tend to hydrogenate organic matter. This point is yet to be proved. Similarly, he believes microbially produced hydrogen may reduce carbohydrates in the presence of certain anaerobic bacteria to give hydrocarbons. ZoBell (66—p. 6) reports that oil-bearing sands and other petroliferous sediments have relatively high reducing intensity and rather low reducing capacity when compared with other sediments and that these properties may be a significant characteristic of source beds of petroleum or producing formations. However, low redox potentials are also found for rocks not considered by geologists as possible source beds. The sample referred to by ZoBell (59—p. 108) is Green River shale of Colorado, a non-marine, brackish-water deposit (3—p. 37). However, the absence of proved origin of petroleum in the thousands of feet of sediment deposited since the Pliocene and the shallow proved depth occurrence of bacteria pose the question whether bacteria do more than "condition" organic material for transformation into petroleum and whether some other combination of processes and conditions does not complete the transformation.

ZoBell (63—p. 3) reports the bacterial production in the laboratory of hydrocarbons ranging from C_{15} to C_{25} from naturally occurring organic matter. Reductive deaminization and decarboxylation of certain protein hydrolysis products result in the formation of substances which are more petroleum-like (58—p. 104). A.P.I. Project 43B has isolated certain petroleum hydrocarbons from bacterial protoplasm in cultures which were developed by ZoBell from marine sediments (50).

Sulphate reducers make and destroy hydrocarbons. They have been found in recent marine sediments, oil-well waters, sulphate deposits, and soils. They are most active in mixed cultures. They will convert stearic acid, oleic acid, or lactic acid into hydrocarbons (62—p. 2). After 3 to 5 days at 28°C. enough hydrogen sulphide is formed to inhibit oxidation of petroleum hydrocarbons.

Sulphate-reducing bacteria reduce sulphate to hydrogen sulphide and under certain conditions to free sulphur in the presence of oil, and produce acid. Such bacteria from marine mud are functional up to at least 90°C. (194°F.) (56—p. 5) and in at least a 15 per cent solution of sodium chloride. They are inhibited by 800 to 900 p.p.m. hydrogen sulphide or a pH less than 6.0. The presence of carbonates, however, prevents a reduction in pH (31). A few types of sulphate-reducing bacteria oxidize solid paraffins, kerosene, decane, tetradecane, and cetane only when free oxygen is excluded. They prefer certain hydrocarbons to others and do not attack some hydrocarbons at all. Their growth is promoted by 55 p.p.m. ferrous iron and one tenth that concentration inhibits hydrocarbon oxidizing bacteria (56—p. 4).

Sulphate-reducing bacteria appear to increase the A.P.I. gravity of petroleum. Athabaska tar having a specific gravity of 1.12 was determined to have a specific gravity of 1.0 after inoculation with sulphate-reducing bacteria (62—p. 7). Sulphate-reducing bacteria release oil from shale (62—p. 7), but there is no indication that this is not due to their surface active tendency to release oil already formed.

Lipolytic anaerobes which decompose naturally occurring fats are widely distributed in recent marine sediments, oil well brines, Athabaska tar sand, asphalt, and paraffin earth (60—p. 2). It has been suggested by Trask and Maier 40—p. 176) that fats may occur as insoluble calcium, magnesium, and aluminum soaps in recent marine sediments.

ZoBell (55—pp. 3–4; 61—p. 2; 63—p. 5; 64—p. 3) has listed the salts of several heavy metals, including nickel, cobalt, copper, bismuth, lead, vanadium, molybdenum, and zinc, which in certain concentrations inhibit bacterial activity. Less than 0.1 per cent vanadium chloride does not inhibit sulphate reducers but more than 0.1 per cent may inhibit. No living bacteria were found in 7 samples of Venezuelan crude oil. ZoBell (61—p. 5) suggests that biochemical activities of different types of bacteria may help to explain variations in composition and properties of petroleum.

By virtue of their surface active propensities, bacteria have a tendency to release oil from solid surfaces (62—p. 7). Acids produced by bacteria dissolve carbonates (62—p. 7) thereby liberating adsorbed oil and increasing voids and channels. In addition to the acid formed, quantities of methane and considerable amounts of carbon dioxide are released, the latter increasing the internal gas pressure of the mass.

Several varieties of aerobic bacteria attack petroleum hydrocarbons under certain conditions. Virtually all kinds of hydrocarbons ranging from simple compounds such as methane and ethane to complex waxes and tars are susceptible to bacterial action. In general aliphatic compounds are utilized more readily than aromatic and naphthenic compounds. According to ZoBell long-chain hydrocarbons such as waxes are attacked more readily by bacteria than are short-chain hydrocarbons. Branched-chain hydrocarbons or iso-compounds are destroyed more rapidly than normal and straight-chain homologs (65—p. 368). The

activities of hydrocarbon-oxidizing bacteria, if they are present, might therefore prevent the accumulation of petroleum in certain environments and they may alter the composition of petroleum in other environments.

Sulphate reducers also oxidize marine sediments over a wide range of temperatures but the same cultures of bacteria did not oxidize petroleum in a sand from a depth of 1,299 feet in the Continental Oil Company's Mayberry No. 3 (55—p. 3). What inhibited the oxidation is unknown.

Fourteen samples of California crude were oxidized by bacteria under aerobic conditions. This oxidation could be inhibited by 12 per cent salt and did not occur in 15 per cent salt. Sea water contains 3.5 per cent salt. Brines may contain 10 times as much (55—p. 3). Hydrocarbon oxidizing bacteria occur as deep as 7.5 feet below the sea floor.

CATALYSTS

Naturally occurring substances, both inorganic and organic, commonly occurring in sea water and in sediments might act as catalysts in the origin of petroleum. Summaries of the commonly occurring substances in the sea and in sedimentary rocks are available in the literature (9; 10; 11). Certain metallic elements, such as nickel, vanadium, lead, and iron, are found in petroleum, apparently in some form of organic combination. Decarboxylation of various fatty acids by bacteria at room temperature occurs in the presence of uranium catalysts but it is doubtful if much petroleum is formed by this reaction (49—p. 1). Bacteria and their enzymes, if they exist and are active at depth during geologic time, may act as organic catalysts.

The most common constituents of sedimentary rocks are quartz (SiO_2), various hydrous aluminum silicates, iron oxides, sulphates and chlorides, and various sulphides and carbonates, the commonest carbonate being calcium carbonate. In lesser amounts are other compounds of iron, calcium, and magnesium as well as iodine compounds and alkaline-reacting zeolites.

Additional substances associated naturally with petroleum, which might have a bearing on oil origin but which are not generally considered as possible catalysts, are nitrogen and nitrogenous compounds, and sulphur compounds—hydrogen sulphide and hydrocarbon-sulphur compounds. These occur so widely, both geographically and geologically in petroleum, that they must be accounted for. Radium, carbon dioxide, and helium are not of universal occurrence in petroleum, but radium apparently is commonly present in oil-field waters (2). If radium is universal in oil-field waters, radon, which has been found in petroleum gas, should be expected to be universal.

VARIATIONS IN COMPOSITION AND PROPERTIES OF PETROLEUM

If all the chemical compounds occurring in petroleum were identifiable, solution of the origin of petroleum problem would be less difficult, but the fact remains that petroleum accumulations are not single pure hydrocarbons. Petroleum

is always a mixture of hydrocarbon compounds each of which alone at standard conditions is a gas, a liquid, or a solid.

Hydrocarbon constituents of petroleum oils of most varied types and from widely different sources show an approximate constancy of ultimate composition explainable by Mabery's statement that, although many individual hydrocarbon compounds may be present, they fall into a few homologous series (19—p. 35).

In general the mixtures of hydrocarbons in petroleum tend to vary from sedimentary basin to sedimentary basin, as well as within sedimentary basins. This might be due to differences in source substances, to degree of metamorphism (45) or perhaps to other causes. For some of the differences in composition and properties of petroleum reference may be made to Gruse and Stevens (19).

The interpretation of such variations is complicated by migration not only from source but from one reservoir to another at different times during geologic history. Foreign substances such as rock particles, microfossils and solid organic substances (32) are picked up during migration, and perhaps at the same time components of petroleum are lost to highly adsorptive rock surfaces (8—pp. 315–316; 57—p. 8).

Observations in a single sedimentary basin having a relatively simple orogenic history may have some bearing on studies on the transformation of organic material into petroleum. This simple type, as illustrated in the Orinoco Basin of Venezuela, is bounded on one side by mountains and on the other by a resistant granite foreland. The petroleum occurrences can be classified into belts paralleling the structural trend of the mountains. Such basins originally commence as a trough or shelf on the edge of a continental mass. The continental mass in this case was the resistant granite foreland, which has been a land area since pre-Cambrian. As the marine basin was gradually filled with sediment, it sank. Mountains were uplifted in the weakest and lightest-weight rocks in the deep edge of the basin. Between these mountains and the foreland, the sediments were compressed into series of folds across the basin, paralleling the mountain chains. Near the marginal edge of the foreland where the stratigraphic section thins rapidly to less than 5,000 feet, a zone of normal faults prevents migration from the deeper part of the basin to the littoral edge.

In this type of basin the structures nearest the mountains are commonly flushed by meteoric waters. Beyond these, progressing toward the granitic foreland, belts of structures yield the following: natural gas; natural gas and condensate with commonly heavy asphaltic oil or bitumen between the condensate and edge-water; high A.P.I.-gravity oil fields; medium-gravity oil fields; low-gravity oil fields; and, between the zone of normal faulting and the granitic foreland, "tar" belts. The term "tar" is used for lack of a better name.

Possibly two major groups of phenomena are illustrated in this case: (a) greater metamorphism of petroleum toward the mountains which has been proposed by White (45) and (b) the possibility of an arrested stage in the formation

of petroleum in the "tar" belt. A combination of both conditions may exist in the intermediate belts. The question is raised whether such "tar" belts in the petroleum sequence might be comparable with peat in the coal sequence.

Such "tar" belts contain nothing but "tar" and dry gas analyzed as methane. "Tar" occurs in stratigraphic sections having highly organic, unlithified, wet clays in stratigraphic sections ranging up to approximately 5,000 feet. In the deeper part of the same basin clays of the same texture and age are dark gray, fissile, brittle shale but with very much lower water content and are associated with petroleum and natural gas. The occurrence suggests a parallelism between pressure and origin.

"Tar" ranges from semi-solid to fluid at 60°F., is gummy, viscous, black and heavier than water. Samples as low as the equivalent of 6.3° A.P.I. have been recovered. Refractive indices of 1.42 to 1.43 have been determined. Preliminary examination suggests that it is composed chiefly of carbon and hydrogen with a minor amount of oxygen.

"Tars" from "tar" belts should be further examined to see whether they are identical with asphaltic residuum in petroleum, oxidation products of petroleum hydrocarbons, hydrocarbon residue of partly decayed marine algae, or are an arrested stage in the transformation of organic material into petroleum.

HYDROCARBONS FORMED BY LIVING PLANTS

Many different hydrocarbons are formed in the life cycle of certain plants and animals. The occurrence in petroleum of waxes and other hydrocarbons similar to those produced by plants is widespread (20; 67—p. 121). A.P.I. Project 43B has isolated hydrocarbons from two species of marine bacteria, from one kind of mold, from two fresh-water algae, from one salt-water alga, from pine-tree oil, and from two fresh-water sediments. Heavy hydrocarbons possibly similar to types occurring in petroleum were isolated from living kelp. The hydrocarbons from kelp and fresh-water algae were extremely complex ranging from 19 to 35 carbon atoms. Physical constants and analyses indicate cyclic compounds must be present (49—p. 1). Hydrocarbons derived from the higher plant and animal forms are ruled out geologically because the oldest petroleum occurred before these forms appeared on the earth.

Whitmore (48—p. 124) has pointed out that something like 10 million tons of hydrocarbon material is produced annually by kelp and other primitive type organisms in the seas. The general absence, however, of free hydrocarbons in recent marine sediments (40—pp. 173–175; 42—p. 1461; 59—p. 111) suggests that any hydrocarbons made by the simple plant forms, which have existed during geologic history since the pre-Cambrian, have been destroyed in near surface environments shortly after burial.

Derivatives of plant pigments occur in petroleum and certain pigments of living plants are reported to have been converted in the laboratory into hydrocarbons at a very rapid rate at 180° to 190°C. Whitmore estimates more than

one million tons of hydrocarbon pigments are produced annually by marine plants alone (49—p. 2).

Optical activity in petroleum has been advanced as an argument for the formation of hydrocarbons of petroleum by living plants and animals. Hoefer-Heimhalt (44) postulated that relatively small amounts of a strongly active fraction derived from cholesterol may account for the observed optical rotation. This is consistent with the Engler hypothesis for the formation of petroleum. Engler and Marcusson (15—pp. 212, 254) as well as Zaloziecki and Klarfeld (52) believed that phytosterol and resin acids may be the active constituents present. Freund postulated that terpenes may be important in imparting optical rotation. Zaloziecki and Klarfeld (52) have shown that the optical activity in petroleum is concentrated in about the same boiling range, 250° to 300° C. at 12 millimeters of mercury, for all types of crude petroleum. Fenske and his associates (17—p. 638) have shown that this optical activity is centered near the 400 molecular weight range. Mair and his associates (30—p. 1258) found that maximum optical rotation is concentrated at about 387 molecular weight, corresponding approximately with the conventional naphthenic compound, $C_{28}H_{60}$. However, in agreement with other workers they found that optical activity is observable considerably above and below this maximum. Fenske found that the actual maxima for a variety of American crudes falls in the range of molecular weight about 375 to 425 (17—p. 638). Optical activity is apparently not destroyed below cracking temperatures. On the other hand, it is conceivable that optically active materials might have been formed by thermal decomposition of the high molecular-weight components of petroleum during the distillation process (21).

Oakwood points out that optical activity in petroleum is in the same molecular-weight range as that of the saturated steroid hydrocarbons (50—p. 4). Plants and animals produce large quantities of optically active sterols and Trask (42) and others have found sterols in recent sediments. This has been confirmed by ZoBell. Sterols have not been isolated from petroleum but sterol conversion products might be present.

MATURATION

Maturation of petroleum might have a bearing on origin. There were no higher forms of plant and animal life in the early Paleozoic where the oldest petroleum occurs. It follows that simple forms of life in those periods produced the materials essential for the formation of petroleum. There is no necessity to consider or study such higher forms of life as fish and trees when searching for the origin of petroleum. There is a possibility that these advanced organisms did contribute from late Paleozoic on. The higher forms of life should be of possible interest only if differences between oils formed since late Paleozoic time and oils formed in earlier time can be detected. If there are no such detectable differences, there is no reason to believe that the processes or the source material changed essentially between Cambrian and Pliocene time.

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BURIED PRE-CAMBRIAN HILLS IN NORTHEASTERN BARTON COUNTY, CENTRAL KANSAS[1]

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ABSTRACT

Six buried pre-Cambrian hills in the Kraft-Prusa, Beaver, and Bloomer oil fields are defined by 952 tests drilled within the 160 square miles mapped. These flat-topped hills were quartzite monadnocks on a Cambrian peneplain eroded across pre-Cambrian quartzite, schist, granite, syenite, granite-gneiss, and pegmatite. During the deposition of 220 feet of lower Cambro-Ordovician Arbuckle beds these monadnocks were islands. On their slopes sediments were deposited with 2° to 5° initial dips. They were buried under 340 feet of upper Cambro-Ordovician dolomites, under 40 feet of Ordovician Simpson shale, and probably also under 650 feet of younger pre-Pennsylvanian strata. Erosion culminating in an early Pennsylvanian peneplain exhumed five of the hills. Slight uplift followed. The paleo-outcrop belt of the truncated Cambro-Ordovician dolomites became a youthful karst plain pitted by sinkholes. Solution valleys to 1½ miles in width fringed each resurrected pre-Cambrian hill at the dolomite-quartzite contact. These solution valleys and sinkholes are partly filled with untransported leached residuum (chert, clay, sand) of the Cambro-Ordovician beds and with transported residuum-derived material deposited in them either as non-marine or marine Pennsylvanian conglomerate. In late Des Moines time the pre-Cambrian hills became diminishing islands in a transgressing sea. Limestones of the Missouri series were deposited on their summits. They are now buried under 3,300 feet of Pennsylvanian, Permian, and Cretaceous rocks. Oil is produced from Pennsylvanian limestones, shore-line sands of the Pennsylvanian marine conglomerate, Cambro-Ordovician dolomite, Cambro-Ordovician residual sand, and pre-Cambrian quartzite.

The data obtained in this 4-year sample study were summarized graphically by plotting the height of the hills above the average ground surface, or their depth of burial below it, as ordinates and geologic times as abscissas. The resulting curve summarizes quantitatively the vertical movements experienced by the six quartzite hills from late pre-Cambrian time to the present.

I. INTRODUCTION

Six buried pre-Cambrian quartzite hills in northeastern Barton County, central Kansas, have been discovered in developing the oil fields of the Kraft-Prusa district. These pre-Cambrian hills are now covered by about 3,300 feet of sediments of Cambro-Ordovician, Pennsylvanian, Permian, and Cretaceous age. It is the purpose of this paper to describe these buried hills, to discuss their influence during the deposition of the sedimentary rocks under which they are now buried, to show their relationship to the present oil accumulations, and to summarize their history from pre-Cambrian time to the present.

Location.—As shown on the regional index map (Fig. 1), the area discussed in this paper is located close to the geographic center of the state of Kansas and is in the mid-part of the prolific Central Kansas oil-field province. The diagonally

[1] Presented before the Tulsa, Wichita, and Oklahoma City geological societies in October and December, 1945, and before the Geological Society of America in December, 1945. Submitted to the Board of University Studies of The Johns Hopkins University as a dissertation in partial fulfillment of the requirements for the degree of Doctor of Philosophy. Manuscript received, January 14, 1946.

[2] Gulf Oil Corporation, Gypsy Division, Geological Laboratory. The writer is indebted to the Gulf Oil Corporation for permission to publish this paper which had its inception as a series of commercial reports prepared in 1942 and 1943. Max Littlefield taught his technique for the study of insoluble residues of well cuttings of the Cambro-Ordovician dolomites in Kansas to the writer in 1941 and first introduced the writer to the problem of these buried hills. Charles Ryniker has made many helpful suggestions, particularly with regard to the illustrations. The writer is grateful to Joseph T. Singewald, Jr., and to a number of other geologists for their critical review of the manuscript.

shaded area of 160 square miles in Figure 1 is the area illustrated in all of the succeeding maps. The buried pre-Cambrian hills described underlie the extensive Kraft-Prusa oil field, the Beaver field, and the former Breford field which is now included as the northernmost extension of the Bloomer field. It is therefore with the Barton County portion of the shaded area of Figure 1 that this paper is principally concerned. These 120 square miles in northeastern Barton County together with that part of the north extension of the Bloomer field which lies

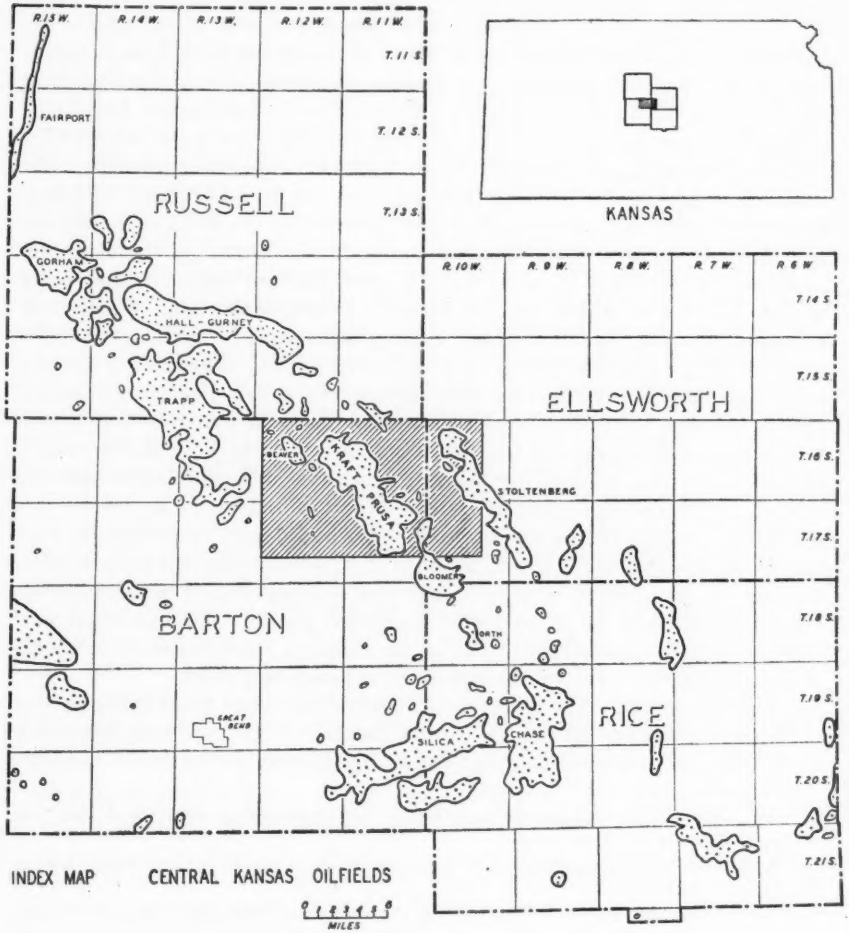


FIG. 1.—Regional index map. Area of this report is shaded.

just east of the Barton County line, comprise what is termed the "Kraft-Prusa district" for convenience of discussion. No buried pre-Cambrian hills are known to underlie the Stoltenberg field; that part of western Ellsworth County which comprises the eastern part of the shaded area in Figure 1 is mapped in order to illustrate the regional surroundings of the buried hills.

Previous work.—In 1935 Koester[3] reviewed the previous literature on Central Kansas and summarized the regional geology of the Central Kansas uplift of which the Kraft-Prusa district is a small part. He noted the presence of pre-Cambrian quartzite in the Breford (now Bloomer) field and correctly recognized the overlap of the Cambro-Ordovician dolomites against what is described as the "Breford quartzite hill" in the present paper. Although but little later geological information has been published, the presence of topographically high areas of pre-Cambrian quartzite in northeastern Barton County was common knowledge among petroleum geologists actively working in the area when the writer began his sample study in 1941. Geologists known to the writer to have contributed substantially to this store of common knowledge include Max Littlefield, Arthur S. Price, and Robert A. Carmody. Littlefield[4] pioneered in the study of the subsurface Arbuckle beds of central Kansas and in the application of the idea, first published by Barwick[5] in 1928, that the truncated pre-Pennsylvanian rocks in Kansas were weathered *in situ* in early Pennsylvanian time by solution processes. Many of the criteria listed in the present paper for establishing correlations within the Cambro-Ordovician and for recognizing the effects of solution erosion on these beds where they were exposed on the early Pennsylvanian land surface are from Littlefield's work. In January, 1942, the writer assisted Littlefield in a study of well cuttings from thirteen tests in T. 16 S., R. 12 W. The results of this sample examination together with other available information were the basis for an unpublished report by Littlefield in which the relationship of the pre-Cambrian quartzite hills in that township to the buried early Pennsylvanian land surface was mapped and in which the origin of the surrounding valleys as solution features was discussed. All of this previous work, and particularly the unpublished studies of Littlefield, served as a solid foundation for the writer's investigation. The present paper summarizes a part of the results of a detailed study of a local area made intermittently by the writer over a period of 4 years.

Other buried hills.—The buried pre-Cambrian hills in the Kraft-Prusa district of central Kansas are not unique features peculiar to that local area but are of fairly common occurrence and widespread distribution in the Mid-Continent.

[3] Edward A. Koester, "Geology of Central Kansas Uplift," *Bull. Amer. Assoc. Petrol. Geol.*, Vol. 19, No. 10 (October, 1935), pp. 1405–26.

[4] Max S. Littlefield, unpublished insoluble residue studies of the subsurface Arbuckle beds of Kansas, 1932–1942.

[5] John S. Barwick, "The Salina Basin of North-Central Kansas," *Bull. Amer. Assoc. Petrol. Geol.*, Vol. 12, No. 2 (February, 1928), p. 188.

In the subsurface of northeastern Oklahoma, Ireland[6] has noted the presence of comparable buried hills. The outcrops of granite at Spavinaw in northeastern Oklahoma as described by Ham and Dott[7] are the eroded tops of such pre-Cambrian hills. In the Ozark region of central Missouri, comparable pre-Cambrian hills projecting into the Cambrian and Cambro-Ordovician beds are of common occurrence as described by Dake and Bridge.[8] Because the extensive erosion which has exposed the hills in the Ozarks has destroyed the post-Ordovician rocks under which they were formerly buried, their history is less completely known than the geologic history of the still buried pre-Cambrian hills described in the Kraft-Prusa district. In the subsurface of central Kansas buried pre-Cambrian hills similar to those described in this paper are known to underlie parts of the Trapp, Orth, and Silica oil fields.

Control.—The local index map (Fig. 2) shows the location of the control points for each of the following maps and the position of the cross sections on Plate I. The larger well symbols indicate the 402 tests from which the writer has examined samples. The smaller well symbols show the location of 550 additional tests. A total of 952 tests were drilled within the area mapped to July 1, 1945. These included 669 oil wells, 263 dry holes, 9 salt-water disposal wells, and 11 drilling wells. The irregular spacing of the well locations shown in Figure 2 is due to the fact that the early wells were drilled on a 10-acre spacing pattern, later wells on a 20-acre pattern, and wells drilled in recent years have been drilled on the 40-acre spacing pattern. In addition, there has been considerable recent redrilling of 40-acre tracts previously considered as condemned by a dry hole.

Oil fields.—The Barton County area mapped in Figure 2 includes the extensive Kraft-Prusa field, the Beaver field, and the former Breford field which is now considered as merged with the Bloomer field through the rather tenuous connection mapped in Sec. 24, T. 17 S., R. 11 W. These fields, together with the minor oil fields mapped in northeastern Barton County, comprise the Kraft-Prusa district. The cumulative oil production of this district is estimated as approximately 25 million barrels to January 1, 1946. About 5 million barrels of this amount was produced during the year 1945. As drilling continues, it is probable that the expanding Kraft-Prusa field will join with and absorb the Beaver field and a number of minor fringing fields, just as it has in the past grown by merging with and absorbing the former Harzman, Krier, Prusa North, Prusa West, Prusa Southeast, and Feltes fields. It is also possible that the Kraft-Prusa field may expand and merge with the Breford part of the Bloomer field.

[6] H. A. Ireland and A. P. Wishart, "Correlation and Subdivisions of the Subsurface Lower Ordovician and Upper Cambrian Formations in Northeastern Oklahoma," *U. S. Geol. Survey Prelim. Chart 5*, Oil and Gas Inves. Ser. (November, 1944).

[7] W. E. Ham and R. H. Dott, "New Evidence Concerning the Age of Spavinaw Granite, Oklahoma," *Bull. Amer. Assoc. Petrol. Geol.*, Vol. 27, No. 12 (December, 1943), pp. 1626–31.

[8] C. L. Dake and Josiah Bridge, "Buried and Resurrected Hills of the Central Ozarks," *Bull. Amer. Assoc. Petrol. Geol.*, Vol. 16, No. 7 (July, 1932), pp. 629–52.

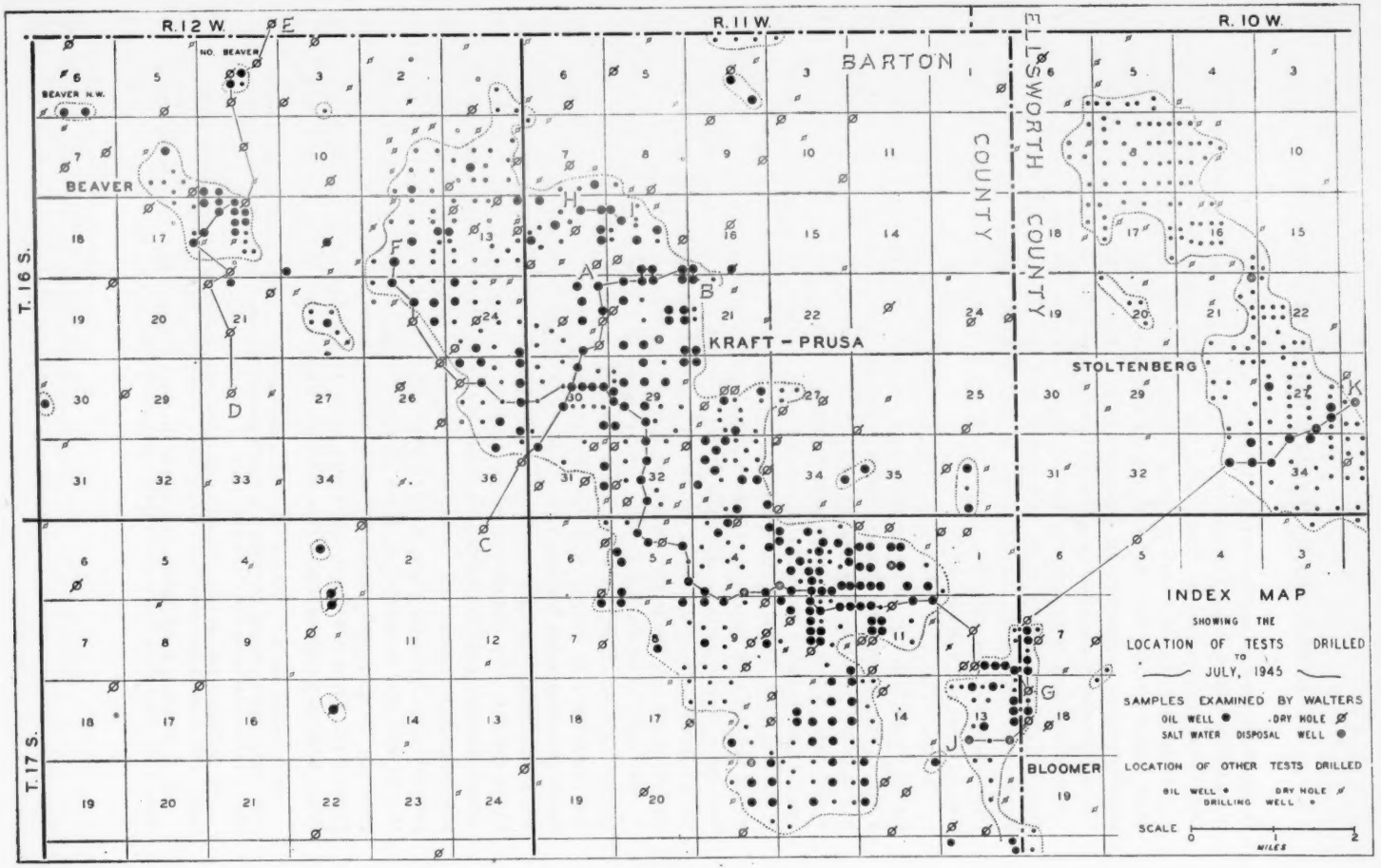


FIG. 2.—Local index map.

The Ellsworth County area mapped in Figure 2 includes 165 wells comprising the north half of the Stoltenberg field. These wells have produced approximately 12 million barrels of oil. The cumulative oil production of the 160 square miles mapped in Figure 2 is, therefore, estimated at approximately 37 million barrels to January 1, 1946. Production data for the four principal oil fields illustrated in Figure 2 are listed in Table I.

TABLE I

PRINCIPAL OIL FIELDS MAPPED IN FIGURE 2*
OIL PRODUCTION (*Barrels*)

Field (County)	*Year of Discovery*	*Year 1945*	*Cumulative through 1945*	*Oil-Producing Wells at End of 1945*	*Oil Wells Mapped in Fig. 2*
Kraft-Prusa (Barton)	1937	4,589,510	19,537,546	430	all
Beaver (Barton)	1934	139,430	1,680,951	23	all
Bloomer (Barton)	1932	2,901,750	21,610,511	262	35
Stoltenberg (Ellsworth)	1931	2,739,690	19,409,226	276	165

* Data from *Oil Weekly* (February 11, 1946), p. 212.

Stratigraphic section.—The generalized stratigraphic section penetrated by wells drilled in northeastern Barton County, Kansas, is illustrated in Figure 3. The outcropping Cretaceous beds have a thickness of 600 feet or less and rest unconformably on Permian. The upper part of the 1,800 feet of Permian consists of redbeds; the middle part, of evaporites including 200 feet of salt; the lower part, of marine limestones with interbedded shales. The underlying 1,100 feet of Pennsylvanian rocks consist of interbedded limestones and shales in the upper part, and of light-colored marine limestones in the lower part. In common with the rest of the extensive Central Kansas uplift,[9] of which the area discussed in this paper is a part, rocks of Mississippian age are absent and Pennsylvanian beds rest unconformably on beds of Ordovician age or older. The sub-Pennsylvanian unconformity is illustrated in the columnar section (Fig. 3), in the natural-scale cross section (Fig. 4), and in the cross sections on Plate I. Over the summits of the buried hills, the Pennsylvanian limestones are in contact with pre-Cambrian quartzite. On the flanks of the hills, dolomites of Cambro-Ordovician age intervene between the Pennsylvanian beds and the pre-Cambrian igneous and metamorphic rocks. Farther from the hills, the Pennsylvanian beds rest on the Ordovician Simpson shale whose thickness is 50 feet or less. In three deep salt-water disposal wells in the Stoltenberg field, Ellsworth County, close to the eastern edge of the area mapped, the Simpson shale overlies 558 feet of Cambro-Ordovician beds which in turn rest on pre-Cambrian granite. These Cambro-Ordovician (Arbuckle) beds consist of cherty dolomite, dolomite, and sandy dolo-

[9] E. A. Koester, "Geology of the Central Kansas Uplift," *Bull. Amer. Assoc. Petrol. Geol.*, Vol. 19, No. 10 (October, 1935), pp. 1405–26.

GENERALIZED STRATIGRAPHIC SECTION

NORTHEASTERN BARTON COUNTY, CENTRAL KANSAS

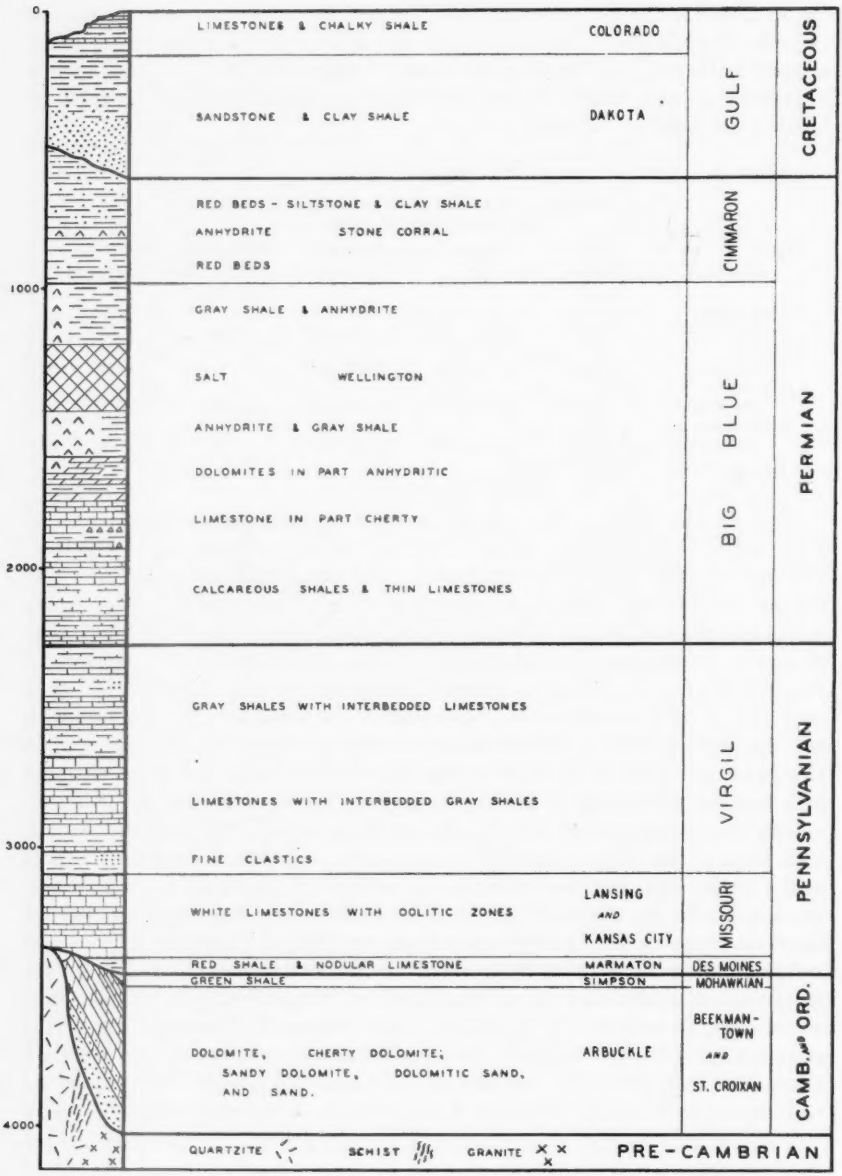


FIG. 3

mite, in downward sequence, with 90 feet of clean porous sand at the base. The almost complete lack of fossils in these Arbuckle beds makes it difficult to place them exactly in the standard time scale. Tentative correlations based on gross lithology and insoluble residue criteria indicate, however, that the upper part of the Arbuckle section in these salt-water disposal wells, possibly the upper two thirds of the section, is Lower Ordovician (Beekmantown) in age and that the lower part of the section is Upper Cambrian (St. Croixian) in age. The lower Arbuckle beds rest unconformably on the pre-Cambrian rocks and overlap against the quartzite hills with progressively younger Arbuckle beds resting on pre-Cambrian. Although important unconformities occur in the columnar section at the base of the Cretaceous, at the base of the Pennsylvanian, and at the base of the Cambro-Ordovician, the Kraft-Prusa district has been a part of the stable continental platform since Cambrian time as indicated by the relatively thin total sedimentary section (3,200 to 3,900 feet), by the lithologic character of the sedimentary rocks, and by the gentle regional dips (1° or less) of the sedimentary strata.

Method of study.—The information presented in this paper is derived largely from a lithologic study of well cuttings. Each of the major oil companies operating in Kansas maintains a permanent file of such cuttings, and these files include samples from almost every test drilled, excepting a few dry holes drilled prior to 1930. In a period of 4 years the writer has examined samples and cores of the lower Pennsylvanian and the pre-Pennsylvanian rocks drilled in 402 tests within the area mapped and had had access to accurate information from most of the other tests. Cores from about twenty-five wells provided the best and most detailed lithologic information. Not much coring has been done in recent years, however, and only two of the cores examined included pre-Cambrian rocks. Good sets of cable-tool cuttings were of great importance in this study. They supplemented the cores in providing the detailed lithology from which local lithologic type sections were established. Even though most of the drilling in recent years in central Kansas has been with rotary tools, a considerable number of cable-tool samples were located. These were derived from early cable-tool wildcat holes, from the few recently drilled cable-tool holes, and from cable-tool "drilling-in" operations below casing set in rotary-drilled holes. The usual production practice is to drill with rotary tools to the top of the "pay" (usually the top of the Arbuckle), to cement casing, and to drill into the oil-bearing section with cable tools. Once the local lithological type sections were established from a study of the cores and cable-tool cuttings, then sets of good rotary samples were very useful. Later considerable information was obtained from poorer sets of rotary samples, but even after much experience in working rotary samples from this local area, the poorest sets yielded no lithologic details or sequence and served only to indicate the presence or absence of the larger lithologic units of the Pennsylvanian, Ordovician, Cambro-Ordovician, or pre-Cambrian rocks. Cable-tool drillers' logs are practically worthless in a study such as this where an attempt is

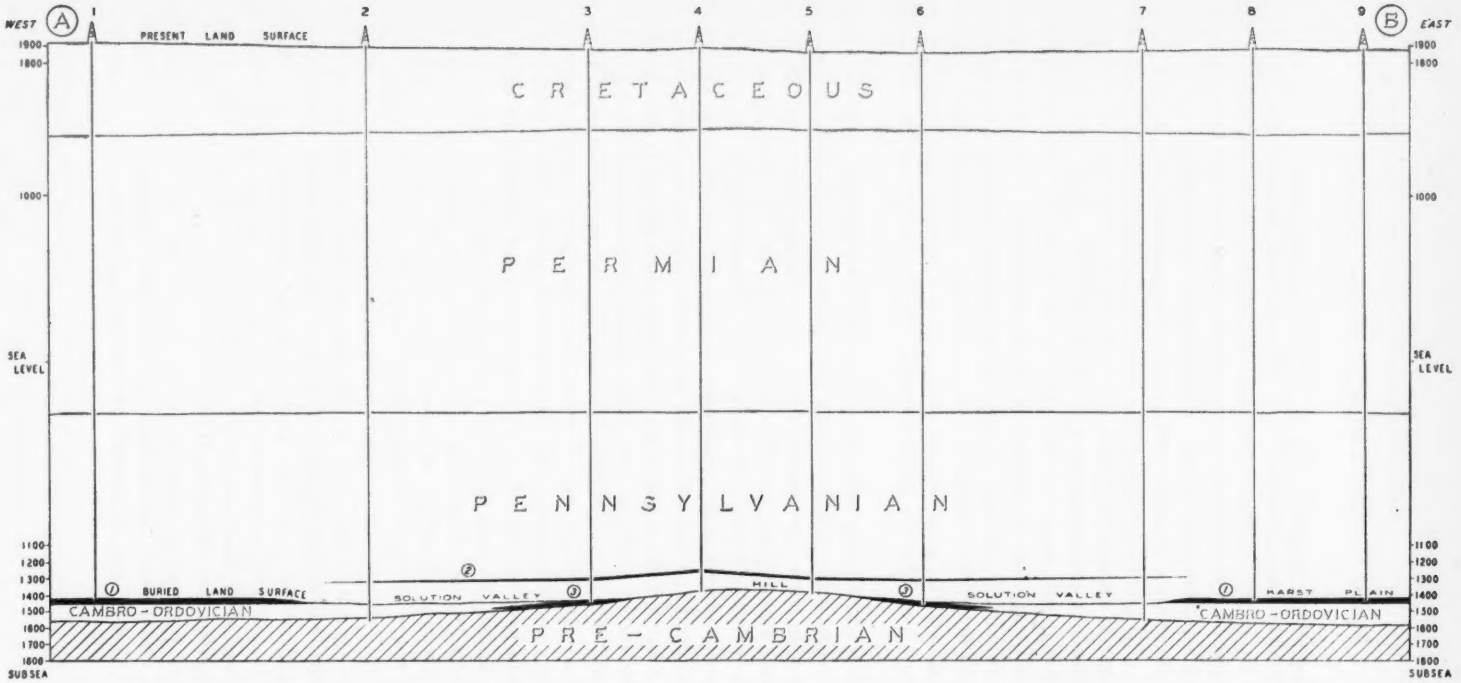


FIG. 4.—Natural-scale cross section through Prusa Hill in T. 16 S., R. 11 W. Length of section, 1½ miles. Oil (solid black) is produced from (1) Cambro-Ordovician dolomite, (2) Pennsylvanian oölitic limestone, (3) Cambro-Ordovician residual sand. Cross section is repeated with further detail as wells No. 1 to No. 9 in cross section *CAB*, Plate I.

made to restore sedimentation environments from a careful lithologic study and such logs were not used. Not many electrical well surveys have been made in the Kraft-Prusa district and no study of electrical logs was undertaken.

Approximately 10,000 samples of well cuttings were examined under a binocular microscope with a magnification of 21 diameters. The lithologic character of the basal Pennsylvanian and the pre-Pennsylvanian rocks was logged in detail on a scale of 10 feet to the inch instead of 100 feet to the inch, the scale most commonly used in Mid-Continent sample work. Insoluble residues were prepared from about 1,350 samples of cable-tool cuttings of the Cambro-Ordovician dolomites following a modification of McQueen's method.[10] The insoluble residues were then examined under a binocular microscope and their lithologic character plotted on the same log as the original sample. Because wells ordinarily penetrate the pre-Cambrian only a few feet, the lithology of the pre-Cambrian cuttings was plotted on the same scale and same log. Cleavage fragments of feldspars in pre-Cambrian cuttings were identified under a petrographic microscope.

II. Buried Pre-Cambrian Surface

The buried pre-Cambrian surface is mapped in Figure 5. The 100-foot contours indicate the present elevation of this surface below sea-level and the symbols indicate the kind of rock present on this surface. Even though this map illustrates the buried pre-Cambrian surface as it is to-day after being subjected to repeated arching and tilting movements in Paleozoic and later time, so gentle were these movements that Figure 5 delineates the essential features of the ancient land surface that was eroded across the truncated pre-Cambrian rocks and that was preserved by burial under sediments deposited in the transgressing Cambro-Ordovician seas. Control points for the topography and areal geology mapped in Figure 5 are the 55 tests drilled to pre-Cambrian from which the writer has examined samples. These are indicated by the larger well symbols; the smaller well symbols indicate the location of 14 additional tests reported to have reached pre-Cambrian. The pre-Cambrian rocks are encountered at depths varying from about 3,300 feet in wells located above the summits of the highest hills to approximately 3,850 feet in the salt-water disposal wells which are the control points for the broad area surrounding the pre-Cambrian hills.

Topography.—The present topography of the buried pre-Cambrian land surface in the 160 square miles mapped in Figure 5 may be described as a smooth gently arched land surface interrupted by a low range of six flat-topped hills which rise about 200 feet above the general level. The broad area surrounding these low hills slopes gently northeastward and southwestward away from them at an average rate of about 100 feet to the mile as indicated by the −1,600 to −2,000-foot (subsea) contours. Most of this slope appears to be due to very gentle post-Ordovician, post-Pennsylvanian, and post-Cretaceous arching move-

[10] H. S. McQueen, "Insoluble Residues as a Guide in Stratigraphic Studies," *Missouri Bur. Geol. and Mines, Bienn. Rept. State Geologist, 1929–1930* (1931), pp. 102–31.

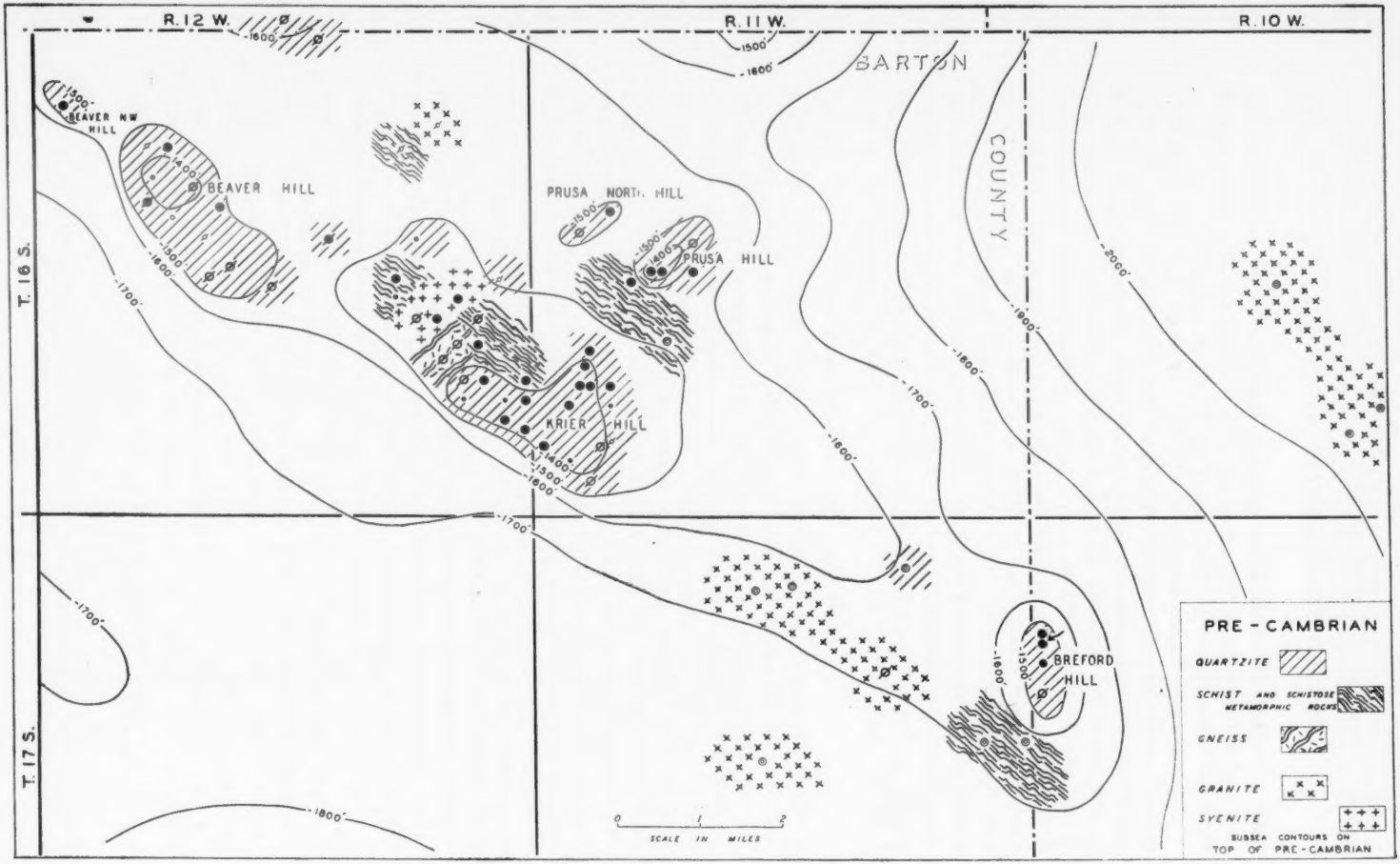


FIG. 5.—Areal geology and topography of buried pre-Cambrian surface. All tests shown drilled pre-Cambrian. Well symbols are repeated from Figure 2; only test producing oil from pre-Cambrian is indicated by arrow on Breford Hill.

ments which affected the entire Central Kansas uplift. It is difficult to evaluate quantitatively the exact amount of such later movement at each individual well location by measuring the amount of folding in the overlying sedimentary rocks because of the problem of distinguishing how much of the present dip of any given sedimentary datum is due to tectonic forces and how much is due to differential compaction of sedimentary sections above a pre-Cambrian basement floor made irregular by the presence of those quartzite hills. The total amount of movement has been small, however, as shown by the gentle dips of the overlying strata—most of them less than 1°. The present slope of the buried pre-Cambrian surface in the broad area surrounding the quartzite hills coincides approximately in direction and degree with the dip of the overlying Cambro-Ordovician Arbuckle beds. It is therefore apparent that the pre-Cambrian surface was less arched when the Cambro-Ordovician sediments were deposited on it and that the topographic surface eroded across the pre-Cambrian rocks in pre-St. Croixian time was a very level and uniform land surface except for this range of low hills.

The summits of the three highest of these pre-Cambrian hills are outlined by the −1,400-foot (subsea) contour and all the hills are defined by the −1,500-foot contour. For ease in discussion, these buried hills have been named "Beaver Hill," "Beaver Northwest Hill," "Krier Hill," "Prusa Hill," "Prusa North Hill," and "Breford Hill" from oil fields, or former oil fields, directly above their summits.[11] Krier Hill, by far the largest of these buried hills, has a fairly flat summit area of about 4 square miles on which the total relief is about 100 feet, and on which there are no slopes steeper than 1° (92 feet per mile). By comparison with its flat summit and with the low relief of the pre-Cambrian surface surrounding the hills, the sides of Krier Hill appear steep, although the steepest actual slope between any two of the present control wells does not exceed 10°. The other hills are also flat-topped with relatively steep sides but are smaller. Their approximate summit areas are: Beaver Hill, 1½ square miles; Breford Hill, about 1 square mile; Prusa Hill, ¼ square mile; Prusa North Hill and Beaver Northwest Hill, about ⅛ square mile (80 acres) each. By comparison with the regularity of the gentle, uniform structures characterizing the subsurface rocks of central Kansas these buried hills are sharp and prominent features. There is a tendency, however, to over-estimate their steepness when examining vertically exaggerated cross sections such as those on Plate I. Unfortunately such vertical exaggeration can not be avoided in cross sections of limited length in which lithologic details are to be included. The true slopes of the pre-Cambrian hills are shown in the small natural-scale cross sections on Plate I. In addition, cross section *AB* (Fig. 4) was drawn to illustrate the natural-scale relationships of a typical hill.

Areal geology.—The areal geology of the buried pre-Cambrian surface is mapped in Figure 5 in so far as it is known. The 69 pre-Cambrian tests define six quartzite areas surrounded by belts of schist or schistose metamorphic rocks.

[11] The former Krier, Prusa, and Prusa North oil fields are now a part of the extensive Kraft-Prusa oil field. The former Breford field is now considered a part of the Bloomer field.

Still farther outward from the quartzite areas, granite or granitic igneous rocks crop out on the buried pre-Cambrian surface. Even though there are not enough pre-Cambrian wells drilled to permit the correct mapping of contacts and to delimit accurately the paleo-outcrop area of each rock type, it is apparent that there is a direct relationship between the areal geology and the topography of the buried pre-Cambrian surface. The areas of quartzite, a rock which is exceedingly resistant to both mechanical and chemical erosion, form the six flat-topped hills. The less resistant schistose metamorphic rocks and granitic igneous rocks underlie the broad plain surrounding the quartzite hills. This direct relationship of areal geology to topography, together with evidence obtained from a study of the Cambro-Ordovician rocks under which this ancient land surface is preserved, leads to the conclusion that these six quartzite hills are residual monadnocks rising above a peneplain eroded in pre-St. Croixian time across a complex terrane of pre-Cambrian igneous and metamorphic rocks.

Pre-Cambrian rock types.—The most commonly encountered pre-Cambrian rock within the area mapped in Figure 5 is *quartzite* which was drilled in 47 of the 69 pre-Cambrian tests. The frequency with which quartzite was encountered is probably due to the fact that it is found at shallower depths than any other pre-Cambrian rock type, because of its occurrence on the summits of buried hills, rather than due to its great relative abundance in the 160 square miles mapped. Several types of quartzite are recognized. Most of the wells, including the greater part of those shown on the cross sections, encountered *granular quartzite*, composed almost entirely of clear quartz grains and characterized by a distinct granularity, in part due to minor amounts of accessory muscovite mica. In several tests the muscovite mica is abundant enough that the rock is described as *micaceous quartzite*. Where mica is present in sufficient amounts to impart a schistosity to the quartzite, as in several tests in the Beaver field, the rock is described as a *schistose quartzite*. An excellent example of micaceous and schistose quartzite is the rock drilled in the Sinclair Prairie Oil Company's Feltes No. 1 in the center of the SE. $\frac{1}{4}$, SE. $\frac{1}{4}$, SE. $\frac{1}{4}$ of Sec. 9, T. 16 S., R. 12 W. (Beaver field), where such quartzite was penetrated for 90 feet with cable tools in an unsuccessful attempt to produce oil in commercial quantity from cracks and joints. In *speckled quartzite*, inclusions of black minerals, most commonly magnetite, are abundant enough to give the rock its speckled appearance. These quartzite types are not mapped separately in Figure 5, but their distinction was a help in studying the sedimentation of the overlapping Cambro-Ordovician beds and of the basal Pennsylvanian conglomerates. The more micaceous and schistose types tend to be somewhat less resistant to weathering; hence, they occur topographically lower on the pre-St. Croixian land surface than the purer quartzite types. On the whole, however, these quartzites were very resistant to the mechanical and chemical erosion to which they were exposed during the time that they cropped out on the pre-St. Croixian and on the early Pennsylvanian land surface. In places, as in the

Gulf Oil Corporation's Case No. 3, Sec. 25, T. 16 S., R. 12 W. (well No. 42, Pl. I), the black magnetite inclusions in speckled quartzite are oxidized to red hematite by weathering on one or both of these former land surfaces.

Schist or schistose metamorphic rocks were drilled in 10 tests located peripherally to the buried quartzite hills. Weathered *muscovite schist* was drilled in several of these, of which the Shell Oil Company's Riemann No. 1, Sec. 23, T. 16 S., R. 12 W. (well No. 38, Pl. I), is an example. That test drilled 76 feet of much weathered schist which contained light-colored micas, considerable red clayey material, chlorite, large books of dark rotted micas, and a few $\frac{1}{4}$-mm. porphyroe blasts of magnetite. Dark *biotite schist* is present in the lower part of the 237 feet of pre-Cambrian metamorphic rocks penetrated in the Sinclair Prairie Oil Company's Mary Prusa No. 4, salt-water disposal well in the center N. $\frac{1}{2}$, SW. $\frac{1}{4}$, SE. $\frac{1}{4}$ of Sec. 20, T. 16 S., R. 11 W. The dark schists in that test appeared to be altered by pegmatitic intrusions. The schists and schistose metamorphic rocks drilled in these two tests and in other tests with shorter pre-Cambrian penetrations were in every case extensively altered and commonly oxidized to a reddish color and clayey composition in the upper 20 to 50 feet as a result of weathering during their exposure on the pre-St. Croixian land surface. Below 88 feet of weathered schist transected by quartz veins, The Texas Company's Peterman No. 4, Sec. 13, T. 17 S., R. 11 W. (well No. 94, Pl. I), drilled 78 feet of fresh *garnet schist* with abundant $\frac{1}{8}$-mm. dodecahedral pink garnets.

Two tests encountered *gneiss*, the Black-Marshall's Veat No. 1, Sec. 26, T. 16 S., R. 12 W. (well No. 41, Pl. I), and its northeast diagonal 40-acre offset. The rock drilled in the Veat No. 1 consists of a groundmass of white to pink orthoclase feldspar, in part weathered and clayey, with quartz present but rare, and with abundant sub-parallel $\frac{1}{4}$-mm. biotite flakes which impart a distinct foliation.

Although only seven wells within the area mapped drilled *granite*, it may be one of the commonest pre-Cambrian types. Probably due to its low resistance to chemical weathering on the pre-St. Croixian land surface, the granite in each of the wells in which it has been encountered occupies a low topographic position on that old land surface. It is therefore probable that granite may underlie a considerable part of the broad plain surrounding the quartzite hills where pre-Cambrian control is scant. Coarse pink biotite granite is well shown in cable-tool cuttings from salt-water disposal wells in T. 17 S., R. 11 W. (wells 66 and 68, Pl. I), and in T. 16 S., R. 10 W. (wells 109 and 111, Pl. I), the deepest wells in the area mapped. In addition to abundant quartz and pink orthoclase feldspar the granite includes biotite, minor amounts of white microcline feldspar, and accessory magnetite. It is ordinarily somewhat weathered in the top few feet with the development of clay and chlorite; this weathered material is in many places incorrectly reported as "granite wash."

Three adjacent 40-acre tests in T. 16 S., R. 11 W., encountered *syenite*. All have short penetrations of the pre-Cambrian with a maximum of 24 feet in the

Gulf Oil Corporation's Wells-Hofmeister No. 2 in Section 23 (well 40, Pl. I). The syenite is much weathered from exposure on one or more old land surfaces until it is now a clayey structureless red rock in the upper few feet which grades down into granitic-textured rock with about 20 per cent dark weathered ferromagnesian minerals and 80 per cent weathered clayey feldspar, in part recognizable as orthoclase. Quartz is completely lacking. The occurrence of syenite was unexpected but not surprising as it was known that more than 150 feet of fresh syenite was drilled in a salt-water disposal well about 10 miles northwest of the Kraft-Prusa district, the Empire Oil and Gas Company's Krud A-3, Sec. 24, T. 15 S., R. 14 W. The presence of syenite in the part of the Kraft-Prusa district in which the pre-Cambrian control points are the most closely spaced merely indicates the complexity of the pre-Cambrian geology that might be expected if control were that closely spaced throughout the district.

One salt-water disposal well drilled *pegmatite.* The 17 feet of pre-Cambrian penetrated in the Shell Oil Company's Soeken B-2 in the NE. $\frac{1}{4}$, NW. $\frac{1}{4}$, NE. $\frac{1}{4}$ of Sec. 21, T. 17 S., R. 11 W., consists of quartz, mica, and white microcline feldspar each of which is present in individual crystals larger than 5 mm., the approximate size of the largest chips present in the rotary well cuttings examined. The salmon-pink orthoclase feldspar which is the most abundant constituent of the biotite granites previously described was not noted. Pegmatitic material was found associated with schistose metamorphic rocks, presumably as intrusive dikes, in the Sinclair Prairie Oil Company's Mary Prusa No. 4, salt-water disposal well in Sec. 20, T. 16 S., R. 11 W. Cable-tool samples from a dry hole in Sec. 34, T. 15 S., R. 12 W., Bailey and Bailey's Galliart No. 1 (well 36, Pl. I), show 7 feet of granitic material interpreted as a pegmatite dike near the base of 142-foot penetration of quartzite and schistose quartzite.

Relationship of igneous and metamorphic rocks.—The relationship of the granitic igneous rocks to the metamorphic rocks is not clearly understood because of lack of evidence at the present time. The association of pegmatitic material with metamorphic rocks in two wells, presumably as intrusive dikes and stringers, indicates that the pegmatitic material is later than the metamorphic rocks. It follows as a fairly reasonable inference that the granites may also be later than the metamorphics and that the intrusion of the granites may have been in part responsible for the metamorphism of the schists and quartzites. This is almost entirely a matter of speculation, however, as most of the wells drilled had only a short penetration into the pre-Cambrian rocks so that igneous-metamorphic contacts were not crossed, and as the contact relations of the igneous and metamorphic rocks on the buried pre-St. Croixian land surface are not mappable with present control. There is, in fact, almost no direct information as to the structural attitude of the metamorphic rocks themselves. Most of the tests which encountered the purer types of resistant quartzite have very short penetrations, many of them only a foot or two, and give no information as to the angle of dip. The

very few tests which penetrated as much as 100 feet of lithologically similar metamorphic rock are inconclusive for it may be inferred from them either that high angle to vertical dips are present or that the pre-Cambrian lithologic units drilled have low-angle dips but a considerable stratigraphic thickness. Those few tests which penetrated the pre-Cambrian 50 to 100 feet and which encountered lithologic variations in the metamorphic rocks provide evidence from which it may be inferred that the angle of dip is probably less than 45°. The two pre-Cambrian cores available from the Kraft-Prusa district showed no bedding or schistosity planes. A schist core from a well 2 miles south of the south boundary of the area mapped, the Gulf Oil Corporation's Grizzel No. 8, Sec. 31, T. 17 S., R. 10 W., showed vertical laminae in fresh dark schist more than 100 feet below the top of the pre-Cambrian, so it is known that high-angle dips can be present. Attention is directed to the difficulty of arriving at conclusions concerning the igneous-metamorphic relationships through a petrographic study due to the necessity of working with finely ground cuttings of rocks, most of which are thoroughly weathered as a result of prolonged exposure on one or more ancient land surfaces.

Some information bearing on the problem of igneous-metamorphic relationships is offered by two wells 12 and 15 miles northwest of the Kraft-Prusa district. They are the Cities Service Oil Company's Ebel 4-B in Sec. 24, T. 14 S., R. 14 W., and Blair's Fink No. 1 in Sec. 16, T. 14 S., R. 14 W., both in the western part of the Hall-Gurney field, Russell County. Sample examination showed that each of these tests had Pennsylvanian resting on pre-Cambrian granite, and that after penetrating 70 feet and 64 feet, respectively, of fresh coarse pink biotite granite, each encountered shistose metamorphic rocks. In each of these wells the igneous rocks appear to be intrusive with contact metamorphic effects present in the underlying metamorphic rocks and with stringers of granitic material present in the upper part of the metamorphic interval in the Cities Service test. There exists, therefore, a precedent for postulating that the granitic igneous rocks in the Kraft-Prusa district may be later than the metamorphic rocks.

Pre-Cambrian history.—So little factual evidence is available concerning the structural attitude and the contact relations of the pre-Cambrian rocks in the Kraft-Prusa district that the pre-Cambrian history can not be accurately reconstructed. It is probable, but unproved, that the intrusion of the granitic igneous rocks caused the metamorphism of the gneiss, schists, and quartzites. There followed a prolonged period of erosion, presumably in late pre-Cambrian time, culminating in an extensive peneplain eroded across this complex terrane of igneous and metamorphic rocks. The areas of resistant quartzite were left as low residual monadnocks rising about 225 feet above the average ground surface. This peneplained pre-St. Croixian land surface was preserved by burial under sediments deposited in the transgressing Cambro-Ordovician seas.

III. Pre-Cambrian Hills in Cambro-Ordovician Time

The pre-Cambrian quartzite monadnocks in the Kraft-Prusa district became islands when the Cambro-Ordovician seas transgressed the peneplained pre-Cambrian surface in Upper Cambrian (St. Croixian) time. Subsequently, they were buried under sediments deposited in the later Cambro-Ordovician seas. Extensive erosion in pre-Pennsylvanian and early Pennsylvanian time, however, removed a considerable part of the Cambro-Ordovician beds under which the hills were once buried. The resulting truncation of the pre-Pennsylvanian rocks is illustrated in the cross sections of Plate I. In order to understand the depositional relationship of the Cambro-Ordovician beds to the pre-Cambrian hills it is, therefore, necessary to piece together such scraps of information as can be obtained from these truncated Cambro-Ordovician rocks. Detailed local correlations of short sections of Cambro-Ordovician rocks penetrated in wells in the Kraft-Prusa district are for that reason of considerable importance in deciphering the history of the pre-Cambrian hills in Cambro-Ordovician time.

A. Correlation of Cambro-Ordovician Beds

Local correlation.—A local type section for the Cambro-Ordovician beds is provided by two salt-water disposal wells drilled with cable tools in the Stoltenberg field. They are the Stanolind Oil and Gas Company and Gulf (Gypsy) Oil Corporation's Frevert No. 1 in the center of the NE. ¼, NE. ¼, NE. ¼ of Sec. 21, T. 16 S., R. 10 W., and the Magnolia Petroleum Company's Schroeder No. 6 in the center of the E. ½, NW. ¼, SW. ¼ of Sec. 26, T. 16 S., R. 10 W. (well 111

TABLE II

Local Type Section of Cambro-Ordovician Beds
(Thickness in feet)

		Stanolind and Gulf's Frevert 1	*Magnolia's Schroeder 6*	*Composite Type Section*
ORDOVICIAN				
Simpson	Green shale	18	21	—
CAMBRO-ORDOVICIAN				
Arbuckle	Cherty dolomite	295	311	300
	White coarsely crystalline dolomite	123	121	120
	Sandy dolomite	45	44	45
Reagan?	Porous sandstone	95	75	85
	Total	558	551	550
PRE-CAMBRIAN				
	Granite	41	22	—

Pl. I). The section drilled in these disposal wells is illustrated in Table II. Local well-to-well correlations of the Cambro-Ordovician section can be made with considerable accuracy. When samples suitable for insouble residue study are available from any test with a penetration of 40 feet or more in the Arbuckle, an accurate correlation checked by several lithologic factors can be made almost without exception, with some part of the local type section of the Cambro-Ordovician in these two disposal wells. Most wells with shorter penetrations can be correlated satisfactorily. Criteria used for correlations are those of Littlefield[12] as described orally to the writer in 1941 and 1942. They include: (1) similarity of detailed sequences of chert types; (2) similarity of sequences of minor clastic zones as shown in insoluble residues; and (3) similarity in sequences of gross lithology factors such as dolomite crystallinity and color, with allowance for variations. Emphasis is placed on matching of detailed sequences of insoluble residue and gross lithology factors. Not much value is placed on a correlation made on the basis of the matching of a single lithology factor without confirmation of other factors in a sequence. Littlefield's subsurface criteria are quite comparable to those established independently at a later date by Cullison[13] in working with outcrops of beds of the same lithologic character and of approximately the same age, except that almost no fossils are present in well cuttings. Detailed local correlations established by these criteria permit the drawing of the bedding lines shown in the cross sections on Plate I and are the basis for estimating the depth to the pre-Cambrian in each of the wells bottomed in Arbuckle. These estimates were used in constructing the map showing the present topography of the buried pre-Cambrian surface (Fig. 5), and the isopach map showing the thickness of the Cambro-Ordovician beds (Fig. 6). Thus through detailed lithologic studies, by using insoluble residues as a tool, a network of well-to-well correlations checked by many "closed traverses" has been established and from this the role of the buried pre-Cambrian hills in Cambro-Ordovician time can be reconstructed.

Regional correlation.—Regional correlation of the subsurface Cambro-Ordovician beds with the section cropping out in Missouri or other type areas is much less satisfactory for the reason that fossils are virtually lacking the well cuttings examined. In some samples, a fragment of one whorl of a silicified gastropod is seen and a few sponge spicules and crinoid stem fragments are present in residues from the upper beds of the Arbuckle section, but on the whole, fossils are a distinct rarity. With fossil evidence almost unobtainable, final regional correlations will have to be based on very careful and detailed correlation of lithologic and insoluble residue sequences from well to well outward from central Kansas to the outcrop of equivalent beds. Until the results of such studies have been pub-

[12] Max S. Littlefield, Unpublished insoluble residue studies of the subsurface Arbuckle beds of Kansas, 1932–1942.

[13] James S. Cullison, "The Stratigraphy of Some Lower Ordovician Formations of the Ozark Uplift," *Univ. Missouri, School of Mines and Metallurgy, Bull. Tech. Ser.*, Vol. XV, No. 2 (June, 1944), p. 11.

lished it is the writer's opinion that the matter should be left open; consequently, no new stratigraphic names are introduced for the local lithologic units of the Cambro-Ordovician beds described and no precise regional correlations are sponsored. There is, however, general agreement among Kansas geologists that the upper 300 feet of cherty dolomite beds in the Kraft-Prusa district are Canadian (Lower Ordovician) in age and it is fairly well (but not entirely) agreed that the basal 85 feet of sandstone, although non-glauconitic, are Upper Cambrian in age There is disagreement about the age of the 120 feet of white coarsely crystalline dolomite and the underlying 45 feet of sandy dolomite. These two members are variously considered as: (1) correlatives of the Gasconade beds (Ordovician) and the Gunter sandstone member of the Van Buren (basal Ordovician), respectively; (2) as Eminence-Potosi (Cambrian) equivalents; and (3) as equivalent to the Roubidoux (Ordovician, post-Gasconade). Since there is no agreement and no basis for arriving at an agreement at the present time, about whether these beds are Upper Cambrian or Lower Ordovician in age, the general term "Cambro-Ordovician" is used in this report for all beds below the Simpson shale and above the pre-Cambrian granite in the two type wells in the area mapped.

B. LITHOLOGIC CHARACTER AND DISTRIBUTION OF CAMBRO-ORDOVICIAN BEDS

Basal sandstone.—The porous basal sandstone member of the Cambro-Ordovician in the two type wells is considered as a possible correlative of the Reagan sandstone of Oklahoma by some workers. It consists lithologically of an aggregate of fairly well sorted angular[14] quartz sand grains. The angularity of the individual sand grains is due to secondary quartz around each individul original grain. The smaller grains are actually euhedral doubly terminated quartz crystals of an approximate prolate spheroidal shape; the larger grains are extensively faceted and tend to approach that form. This sandstone is sufficiently friable that it is broken up into loose individual sand grains when drilled with cable tools. The average grain size is close to $\frac{1}{4}$ mm. (fine to medium sand) but there is a general increase in size grade downward with coarse and very coarse sand grains dominant in the bottom 40 feet. The basal 5 feet include very coarse sand grains and granules to 3 mm. or more in diameter. The sandstone is non-glauconitic. Carbonate cement, interbedded shales, and interstitial clay are lacking, except for a minor amount of dolomite cement in the top few feet. The unconformable contact with the underlying pre-Cambrian granite is placed somewhat arbitrarily within the interval of the sample in which feldspars first appear. Actually some of the feldspar may be locally reworked by the advancing seas and incorporated as arkose in the basal 2 or 3 feet of this sandstone member. Except for this questionable basal arkosic material, the only constituents of this sandstone member which can be recognized as locally derived are a few coarse

[14] Size, shape, roundness, and textural terms are expressed in standard terms and dimensions as summarized by Thomas G. Payne, "Stratigraphical Analysis and Environmental Reconstruction," *Bull. Amer. Assoc. Petrol. Geol.*, Vol. 26, No. 11 (November, 1942), pp. 1697–1770.

quartz grains with black magnetite inclusions from "speckled quartzites" in the near-by quartzite hills and rare 3-mm. flakes of muscovite mica similar to the micas in the local schistose quartzites. This porous sandstone member is the zone sought in drilling salt-water disposal wells. The eight disposal wells completed in it will dispose of an average of about 3,000 barrels of salt water per well each day by gravity flow.

The basal sandstone member is confined to the broad lowland surrounding the quartzite hills. Nowhere within the area mapped does this member crop out in the buried early Pennsylvanian land surface. It is commonly erroneously correlated with a lithologically somewhat similar sandstone which crops out on that former land surface peripherally to the Beaver, Krier, and Prusa buried hills and which there rests on pre-Cambrian quartzites. The latter sandstone is actually a residual sand left by leaching the dolomite from the sandy dolomite member on its updip paleo-outcrop edge where it was exposed to solution erosion on the early Pennsylvanian land surface. The two sands can be differentiated by lateral tracing and by lithological differences. Since the porous basal sandstone member is restricted to the broad lowland surrounding the quartzite hills toward which it thins, as shown in the cross sections on Plate I, it is probable that the quartzite hills were islands during the time represented by the deposition of the 85-foot basal sandstone member of the Cambro-Ordovician.

Sandy dolomite.—The sandy dolomite member includes dolomitic sandstone beds as well as buff, medium crystalline sandy dolomites. Insoluble residues show that the average sand content is close to 50 per cent. Sand grains are predominantly coarse in the top few feet of this member, medium below that, and fine to very fine in the bottom 20 feet. The size sorting is only fair, however, and all size grades commonly occur side by side. This general downward decrease in size is the opposite to that found in the basal sandstone member. Individual sand grains are subround to subangular or angular with secondary crystal facets commonly present but less characteristic than in the basal sandstone member. Sandy quartzose chert comprises 25 to 50 per cent of the top 5 feet of the sandy dolomite member. In it separate scattered sand grains are set in a matrix of clear to translucent quartz. In addition, this quartz matrix includes rare clastic red grains (probably derived from the pre-Cambrian), hazy irregular 1- to 2-mm. oölitoid bodies, and unfilled voids and vugs a part of which are lined with drusy quartz crystals. The distinctive lithologic character of this sandy chert or sedimentary quartzite makes it a zone readily recognized both in cuttings and in insoluble residues. The sandy dolomite member is ordinarily clay free, or nearly so. Pre-Cambrian-derived quartz sand grains with black inclusions (commonly magnetite) are sparingly present, and a few 3-mm. muscovite flakes are found in it in the vicinity of Beaver Hill. The sandy dolomite member is present over the entire area mapped except on the summits of the six pre-Cambrian hills. It rests unconformably on the basal sandstone member in the broad area surrounding the hills, and overlaps directly on pre-Cambrian on the flanks of each

of the quartzite hills as illustrated in Plate I. Erosion in pre-Pennsylvanian and early Pennsylvanian time truncated the updip edge of the sandy dolomite member in the central part of the area mapped. On its early Pennsylvanian paleo-outcrop surrounding the Beaver, Krier, and Prusa hills it was weathered to a residual sand by leaching of its carbonate content. This residual sand is an oil reservoir in the Kraft-Prusa and Beaver oil fields.

Sediments of questionable age underlie marine Pennsylvanian beds and rest on pre-Cambrian on the north flank of Krier Hill. Lithologically these consist of porous sandstone with intercalated beds of red clay and schist-like micaceous shale one to three feet thick. These non-carbonate beds whose maximum thickness is about 40 feet are well shown in cores from an early dry hole, the Gulf Oil Corporation's Dolechek No. 1 in the center of the N. ½, NE. ¼, SW. ¼ of Sec. 24, T. 16 S., R. 12 W., and in cable-tool cuttings from oil wells which now offset the Dolechek in all directions. They are either (a) basal Pennsylvanian clastics, forming a conglomeratic deposit on the flank of Krier Hill, or (b) a local facies of the sandy dolomite member of the Cambro-Ordovician (leached to residuum by weathering on the early Pennsylvanian land surface), deposited in a special local environment. Although red clays and interbedded shales are not known to be present in the sandy dolomite member elsewhere within the area mapped, the interpretation that these beds represent a local facies of this member is in accord with the known distribution of pre-Cambrian rock types as mapped in Figure 5 and with the topography of the pre-Cambrian surface. The depositional environment for this local facies may be reconstructed as follows. In a sheltered cove (indicated by the indentation of the −1,400-foot contour in Figure 5 and by the horseshoe-shaped arc of pre-Cambrian outcrop in Figure 6) these sand grains, red clays, and micaceous shales were deposited together with dolomite in the Cambro-Ordovician sea as a local shore-line facies of the sandy dolomite member in an environment protected from the waves and currents of the open ocean. A local source for the red clays was the thoroughly rotted red syenite such as that present in the Gulf Oil Corporation's Hofmeister No. 2 in the center of the N. ½, SW. ¼, NW. ¼ of Sec. 24, T. 16 S., R. 12 W. (about 1,870 feet northwest of the Gulf's Dolechek No. 1), and a local source for the schist-like micaceous clays was the varied schistose metamorphic rocks such as those present in Black-Marshall's Dolechek No. 1 in the center of the SE. ¼, SW. ¼ of Sec. 24, T. 16 S., R. 12 W. (1,650 feet south of the Gulf's Dolechek No. 1). Weathering of this local facies of the sandy dolomite member on the early Pennsylvanian land surface leached the carbonate (as discussed in the chapter on the early Pennsylvanian history of the pre-Cambrian hills), leaving a porous mass of residual sand with intercalated beds of red clay and micaceous shale capped by the residual sandy quartzose chert from the uppermost bed of the sandy dolomite member. From this interpretation of the non-carbonate sediments on the north flank of Krier Hill it may be deduced that the summit of Krier Hill remained an island during the time represented by the deposition of the sandy dolomite member.

This can not be proved, however, because there is not sufficient evidence to rule out the possibility that these non-carbonate sediments are locally transported material of Pennsylvanian age; all the pre-Cambrian sources of sediment mentioned were also available to the Pennsylvanian erosional agents and these agents had access to an early Pennsylvanian paleo-outcrop of the sandy dolomite member as a source of sand grains.

The evidence for a shore line during the time of deposition of the sandy dolomite member is clearer, however, on Breford Hill against whose sides the sandy dolomite terminates and whose summit is still capped by the upper beds of the conformably overlying white coarsely crystalline dolomite member as shown in cross section *JK* (Pl. I). It is therefore apparent that Breford Hill remained an island during the time represented by the deposition of the sandy dolomite member. Since the other quartzite hills rose as high as, or higher than, Breford Hill above the peneplaned Cambrian land surface, it is reasonable to assume that they too were islands at that time. Although the greater part of the evidence needed to prove this has been destroyed by the early Pennsylvanian erosion which exhumed the other five hills, no evidence to the contrary is known and the few scraps of evidence of facies change in the sandy dolomite member which suggest that there was a shore line on the north flank of Krier Hill accord with this assumption. It is accordingly concluded that the buried pre-Cambrian quartzite hills were islands in the Cambro-Ordovician sea during the time represented by the deposition of the 45-foot sandy dolomite member.

Coarse white dolomite.—The white coarsely crystalline dolomite member is lithologically a pure dolomite characterized by a low insoluble residue content. The upper 40 feet of this 120-foot member include small amounts, commonly 1 to 5 per cent, of fragile cherts, translucent cherts, and fine sands. Because the insoluble residue sequence is distinctive, even though the quantity of residue is small, local correlations of tests having 10 to 20 feet of penetration in this part of the section can be made satisfactorily. The middle third of this member is characterized by the almost complete lack of insoluble material. The bottom third, and particularly the basal 20 feet, includes some medium and coarse, rounded and frosted sand grains. These tend to increase in quantity downward and may mark a transition into the conformable underlying sandy dolomite member. Where subjected to weathering on the early Pennsylvanian land surface, the pure dolomites of this member partially dissolve away with the result that cavernous porosity is formed. Continued solution results in cavern collapse with the formation of numerous sinkholes such as those shown in the cross sections on Plate I. In areas from which the white dolomite member has been removed by solution not much residuum remains. What residuum is left consists of pale green clay (where unoxidized) with imbedded sand grains and rare cherts.

The paleo-outcrop belt of the white dolomite member on the early Pennsylvanian land surface occupies a broad area surrounding the buried pre-Cambrian hills and is the principal oil reservoir in the Kraft-Prusa and Bloomer oil fields.

This dolomite member has been completely removed from the crests of all the quartzite hills except for the Breford buried hill where solution riddled patches are preserved, as shown in cross section *JK* (Pl. I). Cable-tool cuttings from Slick, Pryor, and Lockhart's Breford No. 1 (well 102, Pl. I) show 30 feet of white coarsely crystalline dolomite resting on pre-Cambrian quartzite and schistose quartzite. Insoluble residues satisfactorily substantiate the correlation of the 30 feet section in that well with a zone from 5 to 35 feet below the top of the white coarsely crystalline dolomite member in the Stoltenberg field disposal wells. From this correlation it is known that Breford Hill was buried under the upper 40 feet of the white dolomite member and that it remained an island in the Cambro-Ordovician sea during the time represented by the deposition of the lower 85 feet of that member. No comparable figure can be arrived at for the other buried hills because the evidence has been removed by the early Pennsylvanian erosion which stripped the cover of former Cambro-Ordovician sediments from their summits, but each of those hills is now surrounded by a broad paleo-outcrop belt of this member on the early Pennsylvanian land surface, and it is reasonable to assume that they too were once buried under sediments belonging to the upper part of this member and that they were islands during that part of Cambro-Ordovician time represented by the deposition of the lower two-thirds of the 120-foot white coarsely crystalline dolomite member.

Cherty dolomite.—The 300-foot cherty dolomite member of the Cambro-Ordovician includes dolomites of variable crystallinity and color with light buff finely crystalline dolomites predominating. Insoluble residues show that chert is distributed throughout the entire interval in amounts varying from 5 to 60 per cent and averaging close to 25 per cent. Chert types present include smooth-textured, vitreous, flinty cherts; granular, rough-textured, quartzose cherts which grade into drusy crystalline quartz; and soft dull, tripolitic white cherts. Chert colors are predominantly white and brown; the cherts usually have considerable translucency but range from opaque to clear. Oölitic cherts are present at intervals throughout the entire cherty dolomite member and are a characteristic feature of that member. As an aid in establishing local correlations various types of oölites were recognized, such as: oölites with sand-grain centers oölites with concentric rings of alternating quartzose and flinty chert, oölites with radial structure, oölites with massive centers and white rims, individual silicified oölites which appear as free oölites in residues, and oölites of various shapes and sizes. Zones of oölitic chert are commonly associated with and gradational into sandy zones since both types are the depositional product of an environment of agitated shallow water. Zones of sand grains, sandy chert, and oölitic chert are particularly common in the lower 90 feet of the cherty dolomite member. Most of the included sand grains are medium and coarse and are well rounded with a frosted texture. Dolocastic cherts of various types are common. A few thin zones of green clay and interbedded green shales are present. Where the cherty dolomite member was exposed to weathering on the early Pennsyl-

vanian land surface, the dolomite was leached out, leaving a thick mantle of residual cherts in a clay matrix. The cherts are commonly oxidized to bright shades of red and yellow during this process. The extensive erosion and truncation in pre-Pennsylvanian and early Pennsylvanian time completely removed the cherty dolomite member from the immediate vicinity of the pre-Cambrian hills and it is at present confined to the area outside of the 200-foot isopach line in Figure 6. Abundant characteristic residual cherts of this member are preserved, however, in the central part of the Kraft-Prusa district as slumped residuum, filling sinkholes and solution valleys, and are preserved on and near the summits of the pre-Cambrian hills as residual deposits somewhat reworked by early Pennsylvanian erosion-deposition agents. It is therefore concluded that the buried pre-Cambrian quartzites hills were formerly covered by cherty dolomite beds of the 300-foot cherty dolomite member of the Cambro-Ordovician.

C. INITIAL DIPS IN CAMBRO-ORDOVICIAN BEDS

On the flanks of the pre-Cambrian hills and close to the quartzite-dolomite contact, the lower Cambro-Ordovician beds dip 2° to 5° or more quaquaversally outward from each individual hill. These local dips are relatively steep and irregular as compared with the gentle northeastward and southwestward regional dip of 50 to 100 feet to the mile (½ to 1°) of the Cambro-Ordovician beds in the remainder of the area mapped. Outward from the hills these relatively steep local dips flatten so that in a distance of about ½ mile only the gentle regional dip remains. The angle of dip conforms closely to the angle of slope of the pre-Cambrian floor, but is less steep. A very similar relationship of local dips in Cambro-Ordovician rocks to the pre-Cambrian hills buried under them has been described by Bridge and Dake[15] in the Ozark region in Missouri. From a study of a number of pre-Cambrian hills which were formerly buried under Cambro-Ordovician sediments but which are now resurrected and excellently exposed on the present land surface, Bridge and Dake conclude that the local dips, commonly 10° to 20°, in the Cambro-Ordovician dolomites close to the pre-Cambrian hills in Missouri, are depositional features or initial dips. It is therefore thought that the local dips observed in the lower Cambro-Ordovician beds peripheral to the pre-Cambrian quartzite hills in northeastern Barton County are also depositional features, or initial dips.

Measurement of dips.—The measurement of dips is considerably more difficult in a subsurface study than in a study of outcropping sedimentary rocks where bedding is ordinarily a prominent feature. For each dip reading obtained in this subsurface study it was necessary to establish correlations among three wells by matching detailed sequences of insoluble residues and gross lithology in

[15] Josiah Bridge and C. L. Dake, "Initial Dips Peripheral to Resurrected Hills," *Missouri Bur. Geol. and Mines 55th Bienn. Rept.* (1929), pp. 93–99.
C. L. Dake and Josiah Bridge, "Buried and Resurrected Hills of the Central Ozarks," *Bull. Amer. Assoc. Petrol. Geol.*, Vol. 16, No. 7 (1932), pp. 629–32.

order to determine the position of a bedding plane from which the dip could be calculated. To obtain one such dip reading usually involves a whole day's work. The problem of measuring the local dips peripheral to the quartzite hills in the Kraft-Prusa district was further complicated by the extensive early Pennsylvanian solution of the Cambro-Ordovician carbonate rocks near their contact with the pre-Cambrian quartzites, by the short penetration of a number of wells, and by the wide distance between wells. These complications may be illustrated by a consideration of wells 2, 3, and 4 of cross section *CAB* (Pl. I). Well No. 2 encountered the top of the sandy dolomite member of the Cambro-Ordovician at −1,511 feet (subsea) and the top of the pre-Cambrian at −1,542 feet. Well No. 3, located 1,320 feet east of well No. 2 (the standard distance between wells drilled on a 40-acre spacing pattern), encountered the top of the sandy dolomite member, here a leached residual sand, at −1,433 feet, or 78 feet higher than in well No. 2. Since a dip of 92.16 feet per mile equals 1°, the average component of dip between the two wells (with no allowance made for slumping associated with the solution of the sandy dolomite member in well No. 3) is calculated as a little less than 3½°. This is relatively steep as compared to the average regional dip of ½° to 1° depicted at both ends of the same cross section. But if the control points were more closely spaced, even steeper dips might be found. It is estimated that a well located at the undrilled 10-acre location midway between wells 2 and 3 would encounter the sandy dolomite member at −1,490 feet, and the cross section is so constructed. The component of dip between well No. 2 and this new location would then be a little under 2°, and the average component of dip of the 660-foot interval between this new location and well No. 3 should be 5°. The increase in local dip toward the pre-Cambrian hill would then be more conclusively demonstrated than by the use of the average figure of 3½°. It is conceivable that if additional control points were available still closer to well No. 3 that the sharp dip might be still further localized and that it might be found that dips of 10° or more were present for short distances. Such additional close control points are never available, however, because the minimum distance between any two wells in the Kraft-Prusa district is 660 feet as illustrated in wells 3 to 6 of the same cross section which were drilled on the standard 10-acre locations formerly allowed.

In order to show the relationship of the dip of the Cambro-Ordovician beds in the example cited to the slope of the pre-Cambrian surface it is necessary to consider well No. 4 because well No. 3 encountered oil in the residual sand and was completed as an oil well at a total depth of −1,445 feet (subsea) without reaching pre-Cambrian. Well No. 4, located 660 feet north of No. 3, drilled into pre-Cambrian quartzite at −1,378 feet, or 164 feet higher than well No. 2. Since it is located 1,480 feet northeast of well No. 2, the average slope of the pre-Cambrian floor between wells 2 and 4 is calculated as just under 6° as compared with the average component of dip of the Cambro-Ordovician beds of 3½° be-between wells 2 and 3, which conforms with the generalization made that the

local dips of the Cambro-Ordovician beds are related to, but less than, the slope of the underlying pre-Cambrian floor. In most places the control is such that slopes and dips can not be directly measured and it is necessary to make a number of estimates and some assumptions, as in constructing cross section *CAB* through wells 10, 11, and 12. Wells 2, 3, and 4 cited in this example are also illustrated in cross section *AB* (Fig. 4), where the stratigraphy is generalized because of the scale employed in order to construct the cross section with no vertical exaggeration, but where the pre-Cambrian slopes are shown in their true angular relation.

Origin of dips.—The presence of local dips, now interpreted as initial dips, in the lower Cambro-Ordovician beds peripheral to the quartzite hills in the Kraft-Prusa district and the empirical relationship of those dips to the pre-Cambrian hills was early recognized in this subsurface study, but the control points were so located that not enough evidence was available to warrant conclusions about the origin of such dips. In fact, it was long necessary to maintain an alternate working hypothesis that these "dips," derived from stratigraphic correlations based on the matching of like lithologies, did not represent true bedding planes (hence time lines) but that they were only iso-lithology lines drawn across bedding planes (time lines) where the facies was changing in close proximity to the pre-Cambrian surface. This was particularly true when the dip was established on a datum of the top of the sandy dolomite member where the correlations were derived from a matching of clastic zones. For a simple example, consider a theoretical cross section drawn through four wells located at intervals of 660 feet along a straight line. These wells encountered the following section.

Distance →	A	B	C	D
	Pre-Cambrian	Sandy dolomite	White dolomite	White dolomite
		Pre-Cambrian	Sandy dolomite	Sandy dolomite
Depth			Pre-Cambrian	Pre-Cambrian

The white coarsely crystalline dolomite in well C is correlative with the white dolomite in well D, as substantiated by a number of lithologic check points, so that bedding lines (time lines) are essentially horizontal between those two wells. The sandy dolomite in well B is lithologically similar to the sandy dolomite in wells C and D, and sandy dolomite rests on pre-Cambrian in all three wells. Under the reasoning involved in the first hypothesis (initial dip), the sandy dolomite in well B is correlated with the sandy dolomite of like lithology in wells C and D. Bedding lines (time lines) may then be drawn and the component of dip calculated as in the previous example. This results in the interpretation that the Cambro-Ordovician beds dip outward from the pre-Cambrian hill in well A with relatively steep dips between wells B and C which flatten in a short distance away from the pre-Cambrian hill and blend into the gentle regional dip between wells C and D. Under the second hypothesis (facies change), the

concept is held that the sandy dolomite in well B is the lateral (space and time) equivalent of the white dolomite in wells C and D and that the bedding (time) lines are essentially horizontal throughout the sedimentary rocks in the cross section. It follows that the sandy dolomite in well B is younger than the sandy dolomite in wells C and D. The like lithology of the sandy dolomite in all three wells is then interpreted as the result of deposition in like environments, although at different times, for in each well the sandy dolomite is the clastic facies of the white dolomite near its contact with the pre-Cambrian. Thus, lines drawn on correlations established by matching like lithologies, such a line drawn on the top of the sandy dolomite, are not bedding lines but only iso-lithology lines. The influence of the pre-Cambrian hill has been, under this concept, to contribute a flood of sediments to the Cambro-Ordovician sea with the result that there is a facies change toward the pre-Cambrian contact. The problem thus stated in general terms for wells A, B, C, and D is a simplification of the specific problem presented by wells 5, 6, 7, and 8 of cross section *CAB* (Pl. I). Complications involved in this actual case include: (a) the presence in well No. 6 of residual sand leached by solution localized along the quartzite-dolomite contact instead of fresh sandy dolomite, (b) the short penetration of well No. 8, and (c) the fact that the cross section is not drawn through wells in a straight line, but is deviated south of an east-west line in order to include well No. 6, with the result that the distance between wells 5 and 7 is distorted from 1,320 feet to 1,980 feet as drawn. On the natural-scale cross section (Fig. 4), where these wells are repeated, this distortion results in the very minor error that the slope of the pre-Cambrian floor is depicted as 5° instead of the actual 7° average slope between these two wells.

It was only in the last year of the 4-year period during which this subsurface study was in progress that sufficient evidence accumulated to eliminate the need for carrying the hypothesis of strong facies change in the Cambro-Ordovician sediments adjacent to the pre-Cambrian hills as an alternative working hypothesis. This accumulated evidence included the following facts. (1) The lateral persistence of the sandy dolomite as a lithologic member of the Cambro-Ordovician for several miles from the pre-Cambrian hills as illustrated in cross section *JK* (Pl. I). This sandy dolomite member was found to be present in salt-water disposal wells in the Stoltenberg field, about 5 miles east of the nearest pre-Cambrian hill, with its lithology and thickness essentially unchanged, and in those disposal wells it is separated from the pre-Cambrian floor by 85 feet of clastics belonging to the basal sand member, hence, it can not be a facies developed close to the pre-Cambrian contact. (2) The increased knowledge that the Cambro-Ordovician sedimentary rocks in the Kraft-Prusa district include only a small amount of material that can be shown to be derived directly from the local pre-Cambrian rocks. This information is consistent with the low relief and gentle slopes of the pre-Cambrian surface as illustrated in the small natural-scale cross sections of Plate I. These facts may be supplemented by facts ob-

served by Bridge and Dake[16] in central Missouri where similar pre-Cambrian hills are exposed on the present land surface so that the contacts of the pre-Cambrian rocks with the Cambro-Ordovician dolomites, as well as the dip slopes of individual beds within the Cambro-Ordovician, can be traced by actually walking them out. Those authors show that sharp local dips in the Cambro-Ordovician dolomites, commonly 10° to 20°, are present near the pre-Cambrian contact on each of the formerly buried hills. The reader is referred to their publications for the facts and the deductions that they amass to support their conclusion that these local dips are depositional features, or initial dips, rather than features due to later solution, differential compaction, structural movements, *et cetera*. It is therefore through this accumulation of facts and through the direct analogy of the Kraft-Prusa district with the Missouri area studied by Bridge and Dake that the conclusion may be reached that the local dips observed in the lower Cambro-Ordovician beds peripheral to the buried pre-Cambrian hills in the Kraft-Prusa district are depositional features, or initial dips.

D. CAMBRO-ORDOVICIAN HISTORY

The role of the pre-Cambrian quartzite hills in Cambro-Ordovician time, as restored by piecing together the scraps of evidence preserved in the truncated remnants of the Cambro-Ordovician rocks remaining after early Pennsylvanian erosion, may be summarized as follows. (1) The quartzite monadnocks inherited from the Cambrian land surface were left as islands in the shallow Cambro-Ordovician seas during the time represented by the deposition of the 85 foot basal sandstone member, the 45-foot sandy dolomite member, and the lower 85 feet of the white coarsely crystalline dolomite member, or a total of 215 feet of lower Cambro-Ordovician beds. (2) These pre-Cambrian quartzite island-hills contributed only a minor amount of sediment to the transgressing lower Cambro-Ordovician seas. (3) On their submerged flanks the lower Cambro-Ordovician sediments were deposited with 3° to 5° initial dips which were directly related to, but less steep than, the slope of the pre-Cambrian floor. (4) In upper Cambro-Ordovician time these quartzite hills were buried under the uppermost 40 feet of beds of the white coarsely crystalline dolomite member, and under 300 feet of beds of the cherty dolomite member, or under a total of 340 feet of upper Cambro-Ordovician sedimentary rocks, largely carbonates.

IV. Pre-Cambrian Hills in Late Ordovician Time

The pre-Cambrian hills are thought to have been formerly buried under Upper Ordovician sedimentary rocks belonging to the Simpson, Viola, and Maquoketa formations, all of which are now absent in the immediate vicinity. of the hills. *Simpson shale* of Trenton-Black River age[17] is present in the eastern

[16] Josiah Bridge and C. L. Dake, *op. cit.*

[17] W. H. Twenhofel, "Ordovician Strata in Deep Wells of Western Central Kansas," *Bull. Amer. Assoc. Petrol. Geol.*, Vol. 11, No. 1, (January, 1927), pp. 49–54.

of the Stoltenberg field as mapped in Figure 6. These shales are dark green with a glossy luster and a smooth texture. Some beds include fine sand grains. Locally a three foot bed of porous very fine sand composed of angular recrystallized quartz grains, commonly oil-stained, is present. Where exposed to weathering on the early Pennsylvanian land surface, these dark green shales oxidize to shades of red and yellow. Early Pennsylvanian erosion has truncated the Simpson shale in the Stoltenberg field. Its thickness varies from about 40 feet where protected under Viola limestone cover to only a foot or two in the westernmost wells in which it is present. Regional mapping of the distribution of the Simpson shale in central Kansas substantiates the conclusion that the Simpson shale was formerly present over a wide area and that its absence in the Kraft-Prusa district is due to removal by early Pennsylvanian erosion rather than due to non-deposition. *Viola limestone* intervenes between the Simpson shale and the Pennsylvanian in the northeastern corner of the area mapped in Figure 6. Occasionally a few fragments of Viola-type chert are found near the quartzite hills preserved in clastic deposits filling deep solution valleys in the Arbuckle dolomite. It is therefore probable that the limestones, dolomites, and cherty dolomites of the Viola were formerly present above the buried pre-Cambrian hills. *Maquoketa* beds of Richmond age, now present 15 miles northeast of the Kraft-Prusa district, may also have been deposited above the buried pre-Cambrian hills. The present distribution of both the Viola and the Maquoketa beds in basins on either side of the Central Kansas uplift, essentially as mapped by McClellen,[18] offers confirmatory evidence for the former presence of these beds in the Kraft-Prusa district from which they were removed by erosion either in pre-Mississippian time or in late Mississippian to early Pennsylvanian time. In either event, at the end of Ordovician time the pre-Cambrian hills were buried under a known 340 feet of Cambro-Ordovician beds, a known 40 feet of Ordovician Simpson shale, and under a probable minimum of 100 feet of combined Viola and Maquoketa, or under an estimated total sedimentary section, largely carbonates, with a minimum thickness of 480 feet.

V. Pre-Cambrian Hills in Silurian and Devonian Time

Sedimentary rocks of Silurian and Devonian age are absent in the area mapped but present 30 miles northeast in the Salina basin as early recognized by Barwick.[19] There beds of middle Silurian (Niagaran) and middle Devonian (Onondaga to Hamilton) age are present and they are commonly termed "Hunton" although the Devonian beds are younger than any of the Hunton of Oklahoma from which the name was derived. The combined thickness of these Silurian and Devonian beds, largely dolomites, is 0–500 feet. The variation in thickness is largely due to extensive pre-Mississippian truncation. There is no

[18] Hugh W. McClellen, "Subsurface Distribution of Pre-Mississippian Rocks of Kansas and Oklahoma," *Bull. Amer. Assoc. Petrol. Geol.*, Vol. 14, No. 12 (December, 1930), pp. 1535–56.

[19] John S. Barwick, "The Salina Basin of North-Central Kansas," *Bull. Amer. Assoc. Petrol. Geol.*, Vol. 12, No. 2 (February, 1928), pp. 177–99.

local evidence within the area mapped as to whether the absence of the Siluro-Devonian beds in the Kraft-Prusa district is due to erosion or due to non-deposition, but the extensive regional truncation of the Hunton beds together with their present distribution, essentially as mapped by McClellen,[20] suggests that they were formerly present in northeastern Barton County. It is probable that these beds were somewhat thinner above the positive area which is now the Central Kansas uplift. It is therefore reasonable to assume that at the end of middle Devonian time the pre-Cambrian hills in the Kraft-Prusa district were buried under an estimated 200 feet of Silurian and Devonian beds in addition to an estimated 100 feet of Ordovician beds, a known 40 feet of Ordovician Simpson shale, and a known 340 feet of Cambro-Ordovician, or under an estimated total sedimentary section of approximately 700 feet.

Beginning in late Devonian time, extensive pre-Mississippian erosion truncated the Silurian and Devonian beds in the Salina Basin and probably also removed whatever thickness of these beds may have been deposited in the Kraft-Prusa district. It is the interpretation of Moore and Jewett[21] that the erosion at this time not only removed any Hunton beds formerly present but also removed the Maquoketa and Viola beds from northeastern Barton County. While the extent of this pre-Mississippian erosion in the Central Kansas uplift area can only be inferred at the present time due to the removal of evidence by later erosion in late Mississippian to early Pennsylvanian time in the same areas, the inferred pre-Mississippian paleogeology as mapped by Moore and Jewett in the vicinity of northeastern Barton County is reasonable and it is therefore probable that at the beginning of Mississippian time the summits of the buried pre-Cambrian hills in the Kraft-Prusa district were only 380 feet beneath the average land surface.

VI. Pre-Cambrian Hills in Mississippian Time

Sedimentary rocks of Mississippian age are absent in central Kansas. From the present widespread distribution of the Mississippian rocks on all sides of the Central Kansas uplift and from their extensive truncation by late Mississippian to early Pennsylvanian erosion, it is reasonable to infer that beds of Mississippian age were formerly present above the buried hills in the Kraft-Prusa district. To the northeast in the Salina basin, Mississippian shales of Kinderhook age have a present thickness of as much as 250 feet[22] and Mississippian limestones of Kinderhook, Osage, and Meramec have a combined thickness of about 350 feet as mapped by Lee.[23] It is therefore probable that sedimentary rocks of Mississippian age of an unknown thickness but of a probable order of 350 feet were deposited

[20] Hugh W. McClellen, *op. cit.*, Fig. 2.

[21] Raymond C. Moore and John M. Jewett, "Oil and Gas Fields of Kansas," *Colorado School of Mines, Mines Magazine* (October, 1942), Fig. 6.

[22] Wallace Lee, "Subsurface Mississippian Rocks of Kansas," *State Geol. Survey Kansas Bull. 33* (1940,) Pl. 3.

[23] Wallace Lee, "Relation of Thickness of Mississippian Limestones in Central and Eastern Kansas to Oil and Gas Deposits," *State Geol. Survey Kansas Bull 26* (1939), Pl. I.

in northeastern Barton County. Since these Mississippian sediments were deposited above a known 40 feet of Ordovician Simpson shale and a known 340 feet of Cambro-Ordovician dolomites, it may be estimated that at the close of Meramec time the pre-Cambrian hills in the Kraft-Prusa district were buried under a total sedimentary section of about 750 feet.

Extensive erosion which can be dated as post-Meramec (Mississippian) and pre-Marmaton (Pennsylvanian) removed the Mississippian sedimentary rocks from the Central Kansas uplift and stripped the pre-Mississippian rocks from the summits of the pre-Cambrian hills in the Kraft-Prusa district. Pennsylvanian rocks of Marmaton (upper Des Moines) age now rest on pre-Cambrian in the central part of the Kraft-Prusa district (see cross sections, Pl. I) and on the beveled edges of the slightly tilted rocks of Cambro-Ordovician, Ordovician, and Mississippian (Meramec) age northeastward or basinward from the area mapped. There is no way of knowing exactly how much of this erosion took place in late Mississippian time and how much took place in early Pennsylvanian time. It is apparent, however, that the last phases of this erosion took place in Pennsylvanian time and that the unconformity surface at the base of the Pennsylvanian sedimentary rocks represents an early Pennsylvanian land surface preserved by burial under sediments deposited in the transgressing Marmaton sea. It is probable that this extensive erosion began in late Mississippian (Chester) time.

VII. Pre-Cambrian Hills in Pennsylvanian Time

A. Areal geology of early Pennsylvanian land surface

The sub-Pennsylvanian areal geology is mapped in Figure 6. This map of the paleo-outcrop belts of the truncated pre-Pennsylvanian rocks actually depicts the bedrock areal geology of an early Pennsylvanian land surface which was preserved by burial under Pennsylvanian sediments of Marmaton (upper Des Moines) and Kansas City (Missouri) age. The five areas of pre-Cambrian in the central and northwestern part of Figure 6 are the summits of the Krier, Beaver, Beaver Northwest, Prusa, and Prusa North buried pre-Cambrian hills. It will be noted that the presence of the Breford buried hill straddling the east line of Barton County in T. 17 S., R. 10 W., and T. 17 S., R. 11 W., is not detectable from the areal geologic pattern. Erosion lacked 40 feet of being deep enough to expose the pre-Cambrian quartzite at that locality as illustrated in cross section *JK* (Pl. I.) The five pre-Cambrian areas are surrounded by paleo-outcrop belts of the truncated Cambro-Ordovician Arbuckle beds which occupy the greater part of the area of Figure 6. Their eastern boundary is defined by the paleo-outcrop of the Ordovician Simpson shale which extends through T. 16 S., R. 10 W., in a belt about one mile wide striking north-northwest, closely defined by control wells in the eastern part of the Stoltenberg field. In the extreme northeastern corner of the map, Pennsylvanian beds rest on Ordovician Viola limestone in a small area defined by two tests. The extensive truncation of the pre-Pennsylvanian rocks which outcropped on this early Pennsylvanian land surface is

demonstrated not only by their present sub-Pennsylvanian areal distribution but by their thickness as depicted by isopach lines in Figure 6. These show the thinning of the Cambro-Ordovician Arbuckle beds from 558 feet under the Simpson shale to zero on the flanks of the quartzite hills.

Although the paleo-outcrop belts of the described lithologic members of the Cambro-Ordovician are not mapped, their approximate extent can be determined from the isopach lines because of tha fact that the thinning of the upper Cambro-Ordovician beds is entirely due to erosional truncation. The paleo-outcrop belt of the youngest member, the 300-foot cherty dolomite member, is located between the Simpson shale belt on the east (or the margin of the map on the southeast, south, and west) and the 250-foot isopach line, not drawn, which would be located about mid-way between the 300-foot and the 200-foot lines. The paleo-outcrop area of the underlying 120-foot white coarsely crystalline dolomite member occupies most of the mid-part of the Cambro-Ordovician belt. Peripheral to each of the quartzite hills is a paleo-outcrop belt of the 45-foot sandy dolomite member which varies in width from an inferred width of about 600 feet around the south flank of the small Prusa North Hill to a known width of more than 1½ miles on the gentle north flank of the large Krier Hill. The basal 85-foot porous sandstone member does not crop out on the early Pennsylvanian land surface in the Kraft-Prusa district. Some of the thinning close to the pre-Cambrian areas is due to the absence of this lower member on flanks of the quartzite hills. The closure of the 100-foot isopach line in the southeastern part of Figure 6, straddling the Barton-Ellsworth County line, depicts the thinning which is due to overlap of the lower Cambro-Ordovician beds against the Breford buried hill. The isopach lines mapped in Figure 6 are approximately parallel with the strike of the Cambro-Ordovician beds. The dips of those beds are perpendicular to the isopach lines and toward the thicker sedimentary section. The isopach lines are thus directly related to the strike and dip of the Cambro-Ordovician beds because both the gentle folding and the erosional truncation were consequences of arching movements in pre-Pennsylvanian and early Pennsylvanian time. Thus, from the isopach lines mapped in Figure 6, the present thickness of the Cambro-Ordovician beds can be read, and the strike, the dip, and the areal distribution of the described members can be inferred.

B. PHYSIOGRAPHIC FEATURES OF EARLY PENNSYLVANIAN LAND SURFACE

Figure 7 illustrates the physiographic features of the "fossil" land surface of early Pennsylvanian age preserved by burial under Pennsylvanian and later sedimentary rocks. The principal physiographic features include: (1) a low range of five quartzite hills rising about 50 feet above the average ground surface and coinciding in geographic position with the five areas of pre-Cambrian mapped in the preceding illustration; and (2) a karst plain developed on the broad paleo-outcrop belt of the Cambro-Ordovician Arbuckle dolomite; and (3) a shale belt coinciding with the paleo-outcrop belt of the Simpson shale as mapped in the

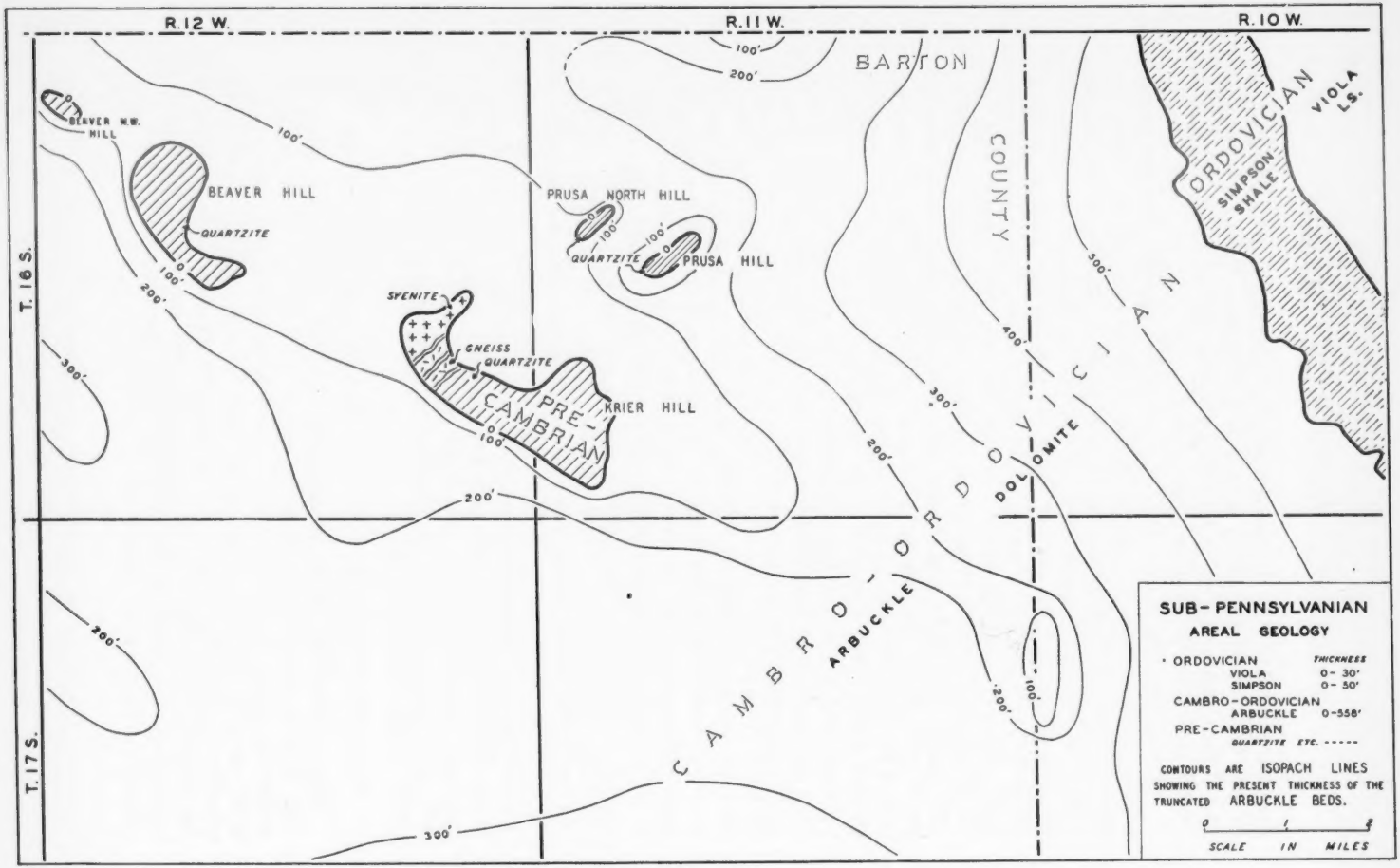


FIG. 6.—Sub-Pennsylvanian areal geology. Depicts bedrock areal geology of buried early Pennsylvanian land surface.

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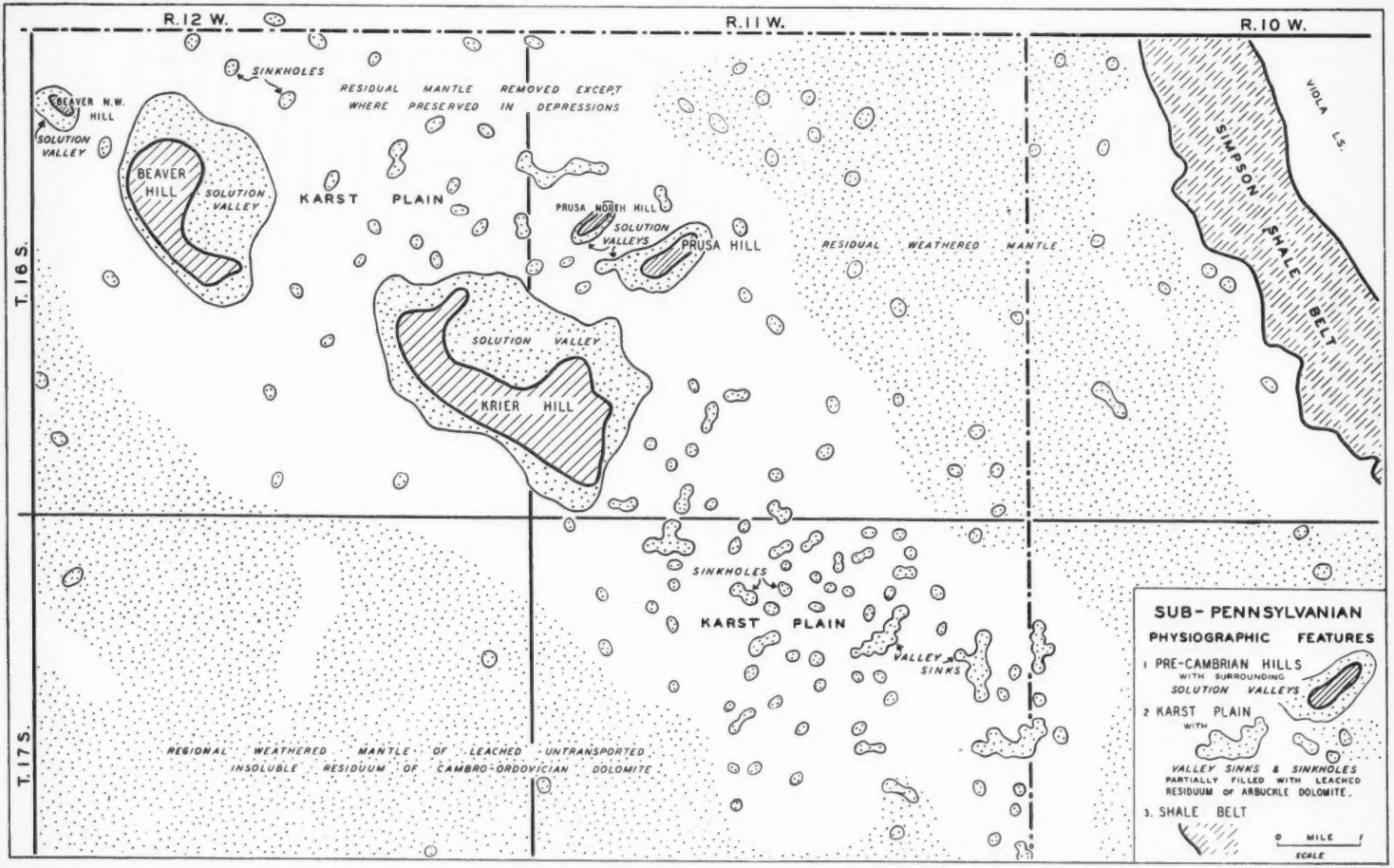


FIG. 7.—Physiographic features and surficial geology of buried early Pennsylvanian land surface. For location of 952 control wells see Fig. 2.

preceding figure. Solution depressions mapped within the karst plain include solution valleys, sinkholes, and valley sinks. Each of these features is defined by excellent control as illustrated in Figure 2 where the location of the 952 control wells is shown. The broad flat divides between solution depressions indicate that the karst plain mapped in Figure 7 is topographically in a stage of late youth.[24]

The solution origin of the features described as sinkholes, valley sinks, and solution valleys can be proved by a study of the sediments now filling these depressions, but is in part determinable from physiographic criteria. All are closed topographic depressions on a former land surface, a land form difficult to explain by mechanical erosional processes. The *solution valleys* surrounding the low pre-Cambrian hills are located at the contact of the resistant pre-Cambrian quartzite and the soluble Cambro-Ordovician dolomite. The inside valley wall is formed by the side of the quartzite hill and the outside valley wall by a low dolomite cuesta. The valley floors are 20 to 80 feet below the summits of the enclosed quartzite hills and a few feet lower than the average elevation of the surrounding dolomite plain. Each of these approximately elliptical valleys is a moat-like topographic depression with no known surface outlet. Each valley encloses a quartzite hill, and no quartzite hills are known in this area which do not have such a surrounding valley. In this connection it should be recalled that the Breford buried hill was not a topographic feature on the early Pennsylvanian land surface. Furthermore, these valleys are directly related in size and shape to the configuration of the quartzite hills. The largest hill, Krier Hill, is surrounded by the broadest and most extensive valley; the smallest hills, Prusa North Hill and Beaver Northwest Hill, are surrounded by the smallest valleys; the hills of intermediate size, Beaver Hill and Prusa Hill, are surrounded by valleys of intermediate size. Moreover, each valley is asymetrical about the hill it encloses, with its broadest width on the most gentle slope of the hill, as particularly well shown on the very gentle north slopes of the Krier and Beaver hills. The intimate relationship of these valleys in size, shape, and location to the quartzite hills is physiographic evidence for their solution origin. The *sinkholes* mapped in Figure 7 are from 10 to 60 feet in depth and are of very limited areal extent as illustrated in the cross sections of Plate I. They are most abundant in the central part of the Kraft-Prusa district on the paleo-outcrop of the nearly pure dolomites of the white coarsely crystalline dolomite member. Many are closely defined by a number of tests, particularly those in the older portion of the Kraft-Prusa field in Secs. 2, 3, 10, and 11 in T. 17 S., R. 11 W., where many wells were drilled on 10-acre locations. Several sinkholes in those sections are known to occupy 20 acres or less. The limited areal extent of these small depressions, their lack of a known surface outlet, and their scattered distribution across a dolomite paleo-outcrop belt are physiographic criteria which suggest that they are sinkholes pitting a karst plain. The *valley sinks* mapped in Figure 7 are each controlled by several tests and appear to be

[24] A. K. Lobeck, *Geomorphology, an Introduction to the Study of Landscapes*, 1st ed. (1939). Diagram, p. 130. McGraw-Hill Book Company, New York.

connected sinkholes; the same physiographic criteria applied to the sinkholes indicate, but do not prove, that these large features are also of solution origin.

It is the interpretation of Mull[25] that stream channels in the Arbuckle surface are present throughout the Central Kansas uplift, of which the area mapped in Figure 7 is a small part. By further extending the valley sinks mapped in Figure 7 through the unknown areas between the present control wells (the closest of which are 660 feet apart), it is possible to connect the valley sinks and sinkholes in a manner simulating dendritic or radial stream drainage patterns. This interpretation is not precluded by the physiographic criteria previously discussed, nor does it violate the present well control. It is therefore necessary to turn to a study of the sediments filling these topographic depressions for information as to their origin. These sediments validate the conclusion that the topographic depressions are of solution origin and that no stream channels characterized by dendritic and radial drainage patterns can be traced by well control throughout the area mapped in Figure 7.

C. SEDIMENTS ASSOCIATED WITH EARLY PENNSYLVANIAN LAND SURFACE

Classification.—Actual proof of the solution origin of the buried sinkholes, valley sinks, and solution valleys mapped in Figure 7 is afforded by the lithologic character of the sediments now filling these valleys. Wells situated directly above these depressions drill through Pennsylvanian marine limestones into as much as one hundred feet of non-carbonate sediments, usually red in color due to extensive oxidation, before encountering either Arbuckle dolomite or pre-Cambrian. In contrast, wells located in the central part of the Kraft-Prusa district over the topographically higher parts of the karst plain between these depressions drill directly out of Pennsylvanian marine limestones into either Arbuckle dolomite or pre-Cambrian. The composition of these valley-filling sediments varies widely from place to place but consists largely of some combination of chert, sand, and clay. These sediments are erroneously considered as clastics in common Kansas oil field usage and are described as "Pennsylvanian basal conglomerate." Edson[26] applied the name "Sooy conglomerate" to such material which she considered "an orogenic molasse deposit." As a result of extensive studies of the insoluble residues of the Cambro-Ordovician dolomites initiated by Littlefield[27] and continued by Walters, it can be proven that a considerable part of these non-carbonate sediments associated with the sub-Pennsylvanian unconformity are untransported residual weathering products. When the lithology of these non-carbonate sediments in cores or excellent cable-tool samples is plotted in detail (on a scale of 10 feet to the inch), exactly the same material is present in the

[25] J. A. Mull, "Stream Channels Applied to the Arbuckle of the Central Kansas Uplift" (abstract), *Tulsa Geol. Soc. Digest*, Vol. 10 (1941–1942), p. 33.

[26] Fanny C. Edson, "The 'Sooy' Conglomerate of Kansas" (abstract and discussion), *Tulsa Geol. Soc. Digest* (1934), pp. 30–32.

[27] Max S. Littlefield, *op. cit.*

lower part of these non-carbonate sediments as is present in laboratory-prepared acid insoluble residues made from fresh Cambro-Ordovician dolomite in well cuttings from a near-by test, and *in exactly the same lithologic sequence.* It is therefore now recognized that these non-carbonate sediments include a considerable amount of untransported residuum of Cambro-Ordovician. Instead of being a clastic "conglomerate" associated with orogenic movements, the sediments associated with the early Pennsylvanian land surface include three types of material of varied origin, all associated with gentle epeirogenic movements. These are classified in Table III as: (1) untransported leached residuum of Cambro-Ordovician, (2) Pennsylvanian non-marine conglomerate, and (3) Pennsylvanian marine conglomerate.

TABLE III

CLASSIFICATION OF SEDIMENTS ASSOCIATED WITH EARLY PENNSYLVANIAN LAND SURFACE

Product	*Residuum* of Cambro-Ordovician	*Conglomerate* (Pennsylvanian)	
		Non-marine	Marine
Source	Fresh carbonate bedrock	Residual mantle and weathered bedrock	Residual mantle, non-marine conglomerate, weathered and fresh bedrock.
Process	Solution	Mechanical erosion and deposition	
Agent	Ground water	Surface run-off water	Ocean waves and currents

Definitions.—The terms "residuum," "non-marine conglomerate," and "marine conglomerate" as applied to deposits associated with the unconformity between the Pennsylvanian and the Cambro-Ordovician in the Kraft-Prusa district are defined as follows. ***Residuum*** is an untransported aggregate of the less soluble constituents of the Cambro-Ordovician dolomites left behind when the carbonates were leached by percolating ground-water. Residuum may be locally slumped during the general lowering of the land surface or during the collapse of a cavern roof. *Non-marine conglomerate* is a detrital aggregate of clastics transported and deposited by non-marine agents such as streams, cloudbursts, *et cetera.* It may have been deposited in seasonally dry stream beds, flood plains, ponds, or at almost any place on the early Pennsylvanian land surface, but is now preserved only where it was protected from later Pennsylvanian marine erosion in the deeper topographic depressions such as solution valleys, sinkholes, and valley sinks. Locally such material fell into collapsed caverns or was carried underground in places where surface streams disappeared into main lines of underground drainage, and was there deposited as cavern fill. *Marine conglomerate* is defined as a detrital aggregate of clastics transported and deposited by marine agents, principally ocean waves and currents. It ordinarily includes a variable amount of carbonate cement.

Criteria.—Criteria for distinguishing residuum, non-marine conglomerate, and marine conglomerate in well cuttings from the area mapped in Figure 7 are here listed.

1. *Residuum* consists entirely of relatively insoluble material such as chert, clay, sand, silt, chert and quartz-lined geodes, quartz crystals, and shale. Silicified fossils such as gastropods and sponge spicules are present but are exceedingly rare. All material present in residuum is also present as impurities in the Cambro-Ordovician dolomites in near-by wells where it is best seen by dissolving away the dolomite and examining the resulting insoluble residues. No material foreign to the Cambro-Ordovician dolomites is present in residuum. The vertical sequence of lithologies in residuum duplicates in minute detail the vertical sequence of lithologies present in laboratory prepared acid insoluble residues made from dolomite sections in near-by wells. There is no evidence of size, shape, or density sorting in residual material and no smooth surfaces or rounded edges indicative of wear by mechanical transportation. Soft tripolitic cherts, fragile cherts, and delicate dolocastic cherts are present. Small quartz and chert lined geodes which lined former vugs in the dolomite are preserved unbroken. Chert fragments in cuttings commonly show clay contacts and the cherts in any given sample from a short vertical interval are strikingly similar in type. There is commonly a gradation in long residuum sections from oxidized material at the top into unoxidized material below. Clay colors range from a deep red in the most oxidized parts through mottled reds and greens into pale green and white in the lower unoxidized part. The clays tend to be "fat" types. Where they include sand grains, individual silicified oölites, or particles of any type of material small enough to be preserved in a single chip in well cuttings, it can be seen that the included grains have a random arrangement. The oxidation of the cherts is milder than in conglomerates and tends to be confined to the edges of individual chert nodules. Residuum grades laterally and downward into undissolved dolomite. Contacts with the undissolved dolomite are irregular and gradational. Relict dolomite "nubbins" surrounded by residuum which are sometimes recovered in cores from the transition zone are not clastic pebbles as shown by their concave surfaces, gradational "fuzzy" edges and protruding fragile points. In applying these criteria to a study of well cuttings, great care must be taken to recognize original surfaces, for instance on cherts, in contrast to the newly fractured surfaces made by the bit during the drilling.

2. *Non-marine conglomerate* is characteristically highly oxidized and the most abundant constituents are brightly colored cherts—red, orange, yellow, and purple—in a matrix of maroon clay. Sand, silt, shale fragments, and quartz crystals are present but admixed with them are minor amounts of material foreign to residuum such as fragments of varied types of pre-Cambrian quartzites. Non-marine conglomerate shows no definite vertical sequence of lithology; to the contrary, it is characterized by its heterogeneity. The distance of transport is ordinarily so short that there is but very little sorting, although sufficient wear

occurs to round a few corners on the hard chert fragments and to destroy most of the soft, fragile, and delicate chert types. Chert fragments in cuttings almost invariably show clay contacts. The cherts and other material in any given sample from a short vertical interval are varied in type. A single short sample may include cherts from three or four different parts of the Cambro-Ordovician Arbuckle dolomites, sand grains from the lower Arbuckle beds, and pebbles of pre-Cambrian quartzite. Non-marine conglomerate almost always overlies residuum and its contact with the underlying oxidized upper beds of the residuum may be difficult or impossible to determine exactly. However, oxidation in the non-marine conglomerate is more extensive than in residuum and the clays are uniformly dark red and the cherts brighter-colored and oxidized to greater depths from the original nodule surfaces.

3. *Marine conglomerate* consists entirely of durable clastic materials such as hard chert types, sand grains, and quartzite pebbles plus a variable amount of carbonate cement. Abundant material foreign to the Cambro-Ordovician dolomites is present, such as pre-Cambrian quartzite pebbles, calcite cement, and limestone nodules. There is no definite vertical sequence of lithology except that in thick marine conglomerate sections the basal clastic beds grade upward into a lime-cemented conglomerate and then into a conglomeratic limestone with included pebbles which become less abundant upward. The basal clastics of the marine conglomerate, almost without exception, show some size sorting, although this is commonly poor. Smooth surfaces and well rounded edges on pebbles of alcomposition—chert, quartzite, crystalline quartz—characterizes marine conglomerate deposits. Chert fragments in cuttings commonly show sand contacts. Material in a given sample of marine conglomerate from a short vertical interval may include a great variety of clastics such as quartzite pebbles from the pre-Cambrian, angular recrystallized sand grains from the lower Arbuckle sandy dolomites, rounded frosted sand grains from the upper Arbuckle, several types of hard cherts from various parts of the Cambro-Ordovician dolomite section, individual free chert oölites, and fragments of broken geodes. Marine conglomerate may rest on fresh Cambro-Ordovician dolomite, on residuum, on non-marine conglomerate, or directly on pre-Cambrian. Where it overlies non-marine conglomerate the contact may be difficult to determine; the marine material is more worn and often includes some carbonate cement. Clays are rare in the marine conglomerate and tend to be concentrated as clayey partings with a semblance of bedding. The cherts are thoroughly and uniformly oxidized. Clastic beds of the basal marine conglomerate grade laterally and vertically into carbonate cemented conglomerate and into conglomeratic marine limestones.

Many of these criteria for differentiating residuum, non-marine conglomerate, and marine conglomerate in well cuttings should be applicable to other regions. They should be helpful in deciphering the geologic history wherever carbonate rocks are drilled beneath an unconformity, or in other words, wherever a "fossil' land surface eroded across carbonate rocks is now preserved by burial under later sediments.

Distribution.—The present distribution of ***residuum*** is mapped in Figure 7 by stippling. In the central area residuum is preserved only as valley-filling material in sinkholes, valley sinks, and solution valleys where it was protected from Pennsylvanian erosion which removed the formerly widespread regional mantle of residuum from the topographically higher parts of the up-arched central area. On either side of the central area, this regional mantle of leached residuum is preserved (except locally) over wide areas as mapped. A few tests within these residuum mantled areas encountered local conditions of deep and intense solution and are mapped as residuum-filled sinkholes. Adjacent to the Simpson shale belt in T. 16 S., R. 10 W., a number of wells in an area totaling about 4 square miles in the Stoltenberg Field encountered fresh dolomite directly beneath Pennsylvanian limestones. This may be an area which was stripped of its protecting cover of Simpson shale so late that a thick residual mantle did not have time to form. The present distribution of the *non-marine conglomerate* is not mapped. It is of limited occurrence as illustrated in the cross sections on Plate I, and is confined to the large solution valleys surrounding the pre-Cambrian hills and to a few of the larger and deeper sinkholes. The present distribution of the *marine conglomerate* is not mapped, but it is more widespread than indicated on the cross section of Plate I. Their scale is such that the occurrence of marine conglomerate could be depected only where more than 5 feet are present as in the topographic depressions. Examination of cores from several tests has shown that a zone of clastics is nearly everywhere present in the basal Pennsylvanian beds at their unconformable contact with the underlying Cambro-Ordovician, although such a zone may be less than an inch in thickness. The present distribution of the sediments associated with the buried early Pennsylvanian land surface is thus intimately related to the physiographic features of that land surface. This is particularly true of the untransported residuum. Figure 7 may also, therefore, be considered as a map of the surficial geology of that early Pennsylvanian land surface with some modifications due to marine erosion by the transgressing Pennsylvanian sea under whose sediments this land surface was buried and preserved.

D. PENNSYLVANIAN HISTORY

The hills resurrected.—The erosion period initiated in late Mississippian time continued in the Central Kansas uplift area during early Pennsylvanian time, probably accompanied by further arching, tilting, and uplifting movements. The pre-Pennsylvanian sedimentary rocks above the summits of the five highest hills were eroded away. These five exhumed hills appeared as low topographic features or "resurrected hills" rising about 25 feet above a peneplained land surface eroded across the truncated edges of rocks of Mississippian to pre-Cambrian age. Erosion lacked 40 feet of being deep enough to uncover the sixth hill, Breford Hill, which still retains a part of its cover of Cambro-Ordovician dolomite and which therefore provides a key to the early history of the hills. In Des Moines time or somewhat earlier this peneplaned land surface was uplifted slightly. Erosion processes were rejuvenated. The low relief of the land surface in the Kraft-Prusa district,

the warm moist climate (as indicated by the extensive Cherokee coal beds in eastern Kansas), and the broad outcrop belt of nearly flat Cambro-Ordovician dolomite provided ideal conditions for erosion by solution.

Solution valleys formed.—Rain falling on the summits of the resurrected pre-Cambrian hills had very little erosional effect on the resistant quartzite. Short surface streams flowed down the hillsides but disappeared underground when they encountered the soluble Cambro-Ordovician dolomites. Solution was thus concentrated at the quartzite-dolomite contact and moat-like solution valleys were formed fringing each hill. As this process continued, the valleys were deepened and widened by leaching of the dolomite, leaving whatever insoluble constituents were contained in the Cambro-Ordovician dolomites as valley-filling residuum. Where solution attacked the sandy dolomite member which rests on pre-Cambrian on the flanks of the Krier, Beaver, and Prusa hills, the included sand grains were freed from their dolomite matrix and left as a residual sand body, now an oil reservoir. Where intense solution attacked the nearly pure white coarsely crystalline dolomite member it dissolved away leaving but little residuum. This consists of pale green clay with a few included sand grains and a very small amount of chert; the dissolving of forty feet of this dolomite may leave only a foot of residuum. Where solution attacked the cherty dolomite member, a thick mantle of residual chert in a clay matrix was left. Although these residual cherts were dropped and slumped by general lowering of the land level and by collapse of caverns, the detailed sequences of chert types were fairly well preserved and no material foreign to the Cambro-Ordovician dolomites was introduced. At the same time that the valleys were being deepened and widened by solution, the surface streams from the hillsides, laden with loose residual material which they were removing from the slopes of the hills, ponded up in the growing solution valleys and dumped their loads, forming the deposits of extensively oxidized non-marine Pennsylvanian conglomerate now found overlying the residuum. As the process of valley filling by residuum and by non-marine conglomerate was simultaneous with the process of valley excavating by solution, it is probable the valleys were at no time very pronounced topographic features.

Karst plain developed.—Contemporaneously with the forming of these fringing solution valleys, erosion processes were active on the broad dolomite plain surrounding the quartzite hills and a karst terrane was developing. There was but little surface drainage. Rain falling on the dolomite plain percolated underground along joints and fractures and partially dissolved away the dolomite. It was at this time that most of the porosity which is the present oil reservoir in the Cambro-Ordovician dolomite in the Kraft-Prusa field was formed. Optimum porosity conditions at any given location are the result of a considerable amount of solution. Too much solution, however, resulted in the formation of large caverns. These collapsed forming sinkholes partly filled with slumped non-porous residuum, largely clay and chert. As the Cambro-Ordovician dolomite karst plain in the Kraft-Prusa district continued to rot away by solution erosion in the warm

moist climate of upper Des Moines time a mantle of leached residuum 2 to 30 feet thick blanketed the entire area.

Marine transgression.—The normal cycle of erosion on the Cambro-Ordovician dolomite karst plain in the Kraft-Prusa district was interrupted in late Des Moines time by a general lowering of the central Kansas area with a consequent encroachment of the upper Marmaton sea. Either just prior to or contemporaneously with the transgression of this sea, gentle arching took place along a northwest axis passing through the central part of the Kraft-Prusa district. As the waves of the transgressing Pennsylvanian sea rolled across the karst plain, they reworked the upper few feet of the thick unconsolidated residual chert mantle overlying the outcrop belt of the cherty dolomite member and incorporated the cherts into basal marine conglomerate, in most places lime-cemented. In the gently arched central portion of the Kraft-Prusa district the surging waves completely planed off the thin residual mantle blanketing the outcrop of the white coarsely crystalline dolomite member and cut into the dolomite itself so that the Pennsylvanian limestones were deposited directly on fresh and porous Combro-Ordovician dolomites. Only where the unconsolidated residuum and non-marine conglomerate beds were protected from erosion in depressions, sinkholes, valley sinks, and in the solution valleys fringing the quartzite hills were they preserved. These isolated areas of residuum are mapped in the central part of Figure 7. Such marine erosion is clearly demonstrated in Derby and Comanche's Dolechek No. 2, in Sec. 32, T. 16 S., R. 11 W. (well No. 54, Pl. I), where only the "root" of a former sinkhole is left. Excellent cable-tool samples from that well show that Pennsylvanian limestones now rest on 13 feet of reduced residuum (white cherts, pale green clays, *et cetera*) which overlie unleached sandy dolomite. This reduced residuum is a type usually found only at the bottom of deep sinkholes underneath a thick section of oxidized residuum. Brightly colored oxidized cherts, red clay, *et cetera*, are completely lacking due to their removal by marine erosion. The residual materials so removed from the central part of the Kraft-Prusa district by marine erosion were dumped into the larger depressions, particularly the broad solution valleys surrounding the Beaver and Krier hills. During the local reworking of this residual mantle by the waves of the Pennsylvanian sea, the cherts were rolled and worn, and some selective sorting took place, particularly along the shore lines.

The hills as islands.—With continued marine transgression the entire Cambro-Ordovician karst plain was inundated and the five resurrected pre-Cambrian hills became islands in the upper Des Moines sea. As the waves pounded against these island-hills, a small amount of fresh pre-Cambrian quartzite was eroded and incorporated along with the reworked residual material into the coarse basal marine conglomerate. In a cove on the north flank of Beaver Hill the waves of a temporary stand of the Pennsylvanian sea winnowed the clay and fine sand from the unconsolidated residuum and non-marine valley-fill, leaving a well sorted chert lag gravel which is now an oil reservoir in Darby's Kultgen No. 4 in Sec. 16, T. 16

S., R. 12 W. (well 26, Pl. I). A little farther from shore the marine Pennsylvanian conglomerate deposited at this time included a sand bar of well sorted fine sand derived by reworking the outcropping Cambro-Ordovician residual sand higher on the flank of Beaver Hill. This sand bar forms a thin but excellent oil reservoir in the Darby's Kultgen No. 2 in Sec. 16, T. 16 S., R. 12 W. (well 27, Pl. I), and in nine other wells along its depositional strike. Still farther from shore in this cove, sorting was less complete and, although the marine Pennsylvanian conglomerate includes the same sand member in the Darby's Jarus No. 3 in Sec. 16, T. 16 S., R. 12 W. (well 28, Pl. I), the sand failed to make a commercial oil reservoir at that location as it is clayey. Thus the waves of the transgressing upper Des Moines sea modified the early Pennsylvanian landscape by leveling it off. The residual material and unconsolidated non-marine conglomerate eroded from the topographically high areas were dumped with some reworking and sorting into any remaining depressions, principally the large solution valleys fringing the Krier and Beaver hills. The basal marine conglomerate so deposited grades upward into 1 to 10 feet of conglomeratic marine limestones which in turn grade upward into normal marine limestones. Throughout upper Des Moines time the summits of the five resurrected quartzite hills in the Kraft-Prusa district remained above water and the hills were a part of an island archipelago.

The hills buried.—The transgression of the Pennsylvanian seas initiated in Des Moines time continued into Missouri time. The five pre-Cambrian quartzite hills were gradually diminishing islands in the transgressing Missouri sea during the time represented by the deposition of the basal 30 feet of Lansing-Kansas City limestones. From the time that the waves of the Missouri sea washed across the highest point on the summit of Krier Hill, the pre-Cambrian quartzite hills have remained buried. The general vicinity of these recently buried quartzite hills was a shoal area in the lime-depositing Missouri seas and thin beds of shallow-water oölitic limestones were deposited intermittently. These oölitic beds and the other limestones of the Missouri series are now draped across the buried quartzite hills in gentle anticlinal folds with a closure of 20 to 50 feet, the highest parts of which approximately coincide with the summits of each of the hills beneath, as illustrated in the cross sections of Plate I. Although this draping may be in part due to differential compaction of the residual material in the solution valleys fringing the quartzite hills, it is largely due to folding as shown by the fact that there is also a gentle anticline in these limestones above Breford Hill which has no fringing solution valley. The oölitic zones in the Lansing-Kansas City limestones produce oil from the higher parts of these very gentle structures directly above the summits of each of the six buried quartzite hills in the Kraft-Prusa district. At the end of Missouri time the pre-Cambrian hills were buried under 230 to 260 feet of marine limestones.

In late Pennsylvanian time the quartzite hills were buried under an additional 800 feet of sediments of Virgil age, mostly marine limestones and shales as shown in the columnar section (Fig. 3). Because even the highest of the quartzite hills

was buried under 230 feet of Pennsylvanian limestones at the beginning of Virgil time, the hills had no influence on the sedimentation of the upper Pennsylvanian marine beds. At the close of Pennsylvanian time, the pre-Cambrian hills were buried under a total of about 1,100 feet of upper Pennsylvanian sedimentary rocks, largely limestones.

VIII. Pre-Cambrian Hills in Permian Time

During Big Blue time, 1,300 feet of marine and evaporite beds were deposited above the buried pre-Cambrian hills. In Cimmaron time an unknown thickness of clastic redbeds was deposited, all but approximately 500 feet of which were removed from the Kraft-Prusa district by pre-Cretaceous erosion as illustrated in the columnar section (Fig. 3). It is possible to estimate the former thickness of the Permian beds because the Stone Corral member of the Cimmaron series persists laterally over considerable distances, permitting correlation with areas where the Permian section is less eroded. Norton's study of the Permian redbeds of Kansas[28] shows that the post-Stone Corral redbeds have a thickness of about 1,300 feet. Since a maximum of close to 300 feet of post-Stone Corral redbeds are still present in the Kraft-Prusa district, it may be estimated that approximately 1,000 feet of upper Permian sediments have been removed by pre-Cretaceous erosion. It may therefore be concluded that at the end of Permian time the pre-Cambrian hills were buried under a known 1,100 feet of Pennsylvanian beds, a known 1,800 feet of Permian beds still present above them, and an estimated 1,000 feet of Permian clastics which were removed by pre-Cretaceous erosion or that they were buried under an estimated total of 3,900 feet of sedimentary rocks.

IX. Pre-Cambrian Hills in Post-Permian Time

Cretaceous beds rest unconformably on truncated Permian redbeds in the Kraft-Prusa district as illustrated in Figure 3. Any Triassic, Jurassic, and early Cretaceous beds that may have been deposited above the hills, together with an estimated 1,000 feet of Permian beds, were eroded in pre-Dakota time so that the sedimentary cover above the buried pre-Cambrian hills was reduced to a thickness of about 2,900 feet in late Lower Cretaceous time.

During late Lower Cretaceous and Upper Cretaceous time a considerable thickness of Cretaceous beds, largely marine, was deposited in northeastern Barton County, all but about 500 feet of which were removed by extensive erosion in Tertiary time. From the regional maps compiled by Reeside[29] it is estimated that the Cretaceous beds had a former thickness of 1,400 feet directly above the summits of the buried pre-Cambrian hills. Thus at the end of Cretaceous time it may be estimated that the pre-Cambrian hills were buried under 4,300 feet of

[28] George H. Norton, "Permian Redbeds of Kansas," *Bull. Amer. Assoc. Petrol. Geol.*, Vol. 23, No. 12 (December, 1939), pp. 1751–1819.

[29] John B. Reeside, Jr., "Thickness and General Character of the Cretaceous Deposits in the Western Interior of the United States," *U. S. Geol. Survey Prelim. Map 10*, Oil and Gas Investig. Ser. (1944).

sedimentary rocks, consisting of 2,900 feet of Pennsylvanian and Permian beds, still present, and an estimated 1,400 feet of Cretaceous sediments.

Erosion initiated in Tertiary time and continuing into the present has removed approximately 900 feet of Cretaceous sediments from northeastern Barton County. In several localities in central Kansas, Tertiary folding has arched the Cretaceous beds into very gentle anticlinal folds which reflect the presence of sharper structures in the underlying beds. No information is available to the writer as to whether such Tertiary folding affected the outcropping Cretaceous beds in the Kraft-Prusa district. The summits of the pre-Cambrian hills, now about 3,300 feet below the average ground surface, are buried under sedimentary rocks of Pennsylvanian, Permian, and Cretaceous age at the present time as illustrated in the columnar section (Fig. 3), and in the natural-scale cross section (Fig. 4).

X. Relation of Oil Reservoir Zones of Kraft-Prusa District to Buried Pre-Cambrian Hills

The reservoir zones producing oil in the Kraft-Prusa, Beaver, Beaver Northwest, Breford (now Bloomer), and other less important oil fields which together comprise the Kraft-Prusa district are genetically related to the six buried pre-Cambrian hills. The Stoltenberg field in Ellsworth County is excluded from the present discussion because no pre-Cambrian hills are known to underlie it. Within the Kraft-Prusa district (the Barton County part of Figure 2 plus the Breford area of the Bloomer field) 504 wells were producing oil on July 1, 1945, from the five reservoir zones listed in Table IV. Four wells which are producing from two zones are counted twice in this tabulation. Two such wells are illustrated as wells 3 and 4 of cross section *AB* (Fig. 4), where the three most important reservoirs are illustrated in their natural-scale relationship above Prusa Hill. This figure alsa illustrates how an oil field which is geographically continuous, location by locotion, is deriving its oil from three distinct reservoirs with totally different histories, lithology of reservoir beds, water levels, and oil reserves. Although separate production figures are not available for these five types of reservoir zones, their relative importance is about in direct ratio to the number of wells producing from each.

The most important oil reservoir is the Cambro-Ordovician Arbuckle dolomite at its unconformable contact with the overlying Pennsylvanian beds. The pre-Cambrian hills are related to this oil reservoir only in that they interrupt the continuity of the Arbuckle dolomite in the Kraft-Prusa, Beaver, and Beaver Northwest oil fields. The greater part of the cumulative oil production of the Kraft-Prusa district has been derived from the 393 wells which are producing from the Cambro-Ordovician dolomites.

Of second importance as an oil reservoir are the Pennyslvanian limestones. Directly above the summits of all six of the buried pre-Cambrian hills these limestone reservoirs produce oil in 56 wells in the Kraft-Prusa, Bloomer, Beaver, and

Beaver Northwest oil fields. The Pennsylvanian limestones are draped over the pre-Cambrian hills in very gentle anticlinal folds which form structural traps. Oil accumulation within these anticlines is modified by local porosity conditions. Limestones of the Virgil series produce from fine pin-hole porosity possibly associated with fractures whereas limestones of the Des Moines series are producing from oölitic zones 3 to 8 feet thick.

The updip edge of the Cambro-Ordovician residual sand produces oil from 40 wells on the flanks of the three largest pre-Cambrian hills—the Krier, Beaver, and Prusa hills—in the Kraft-Prusa and Beaver oil fields. The porosity of this unconformity reservoir was formed in early Pennsylvanian time by the leaching of the sandy dolomite member of the Arbuckle in the solution valleys fringing

TABLE IV

OIL RESERVOIR ZONES OF KRAFT-PRUSA DISTRICT

Reservoir Zone	*Reservoir Type*	*Number of Wells*	*Examples, Plate I*
Pennsylvanian limestones	Structural trap modified by porosity conditions	56	4, 5, 12–15, 43–48
Pennsylvanian sand in basal marine conglomerate	Stratigraphic trap	18	26, 27, 28
Cambro-Ordovician residual sand	Unconformity reservoir	40	3, 6, 16, 24, 25
Cambro-Ordovician (Arbuckle) dolomite	Unconformity reservoir	393	1, 8, 9, 53–80 (except 60, 66, 68, 78)
Pre-Cambrian quartzite	Unconformity reservoir	1	101

the pre-Cambrian hills. Since this oil reservoir did not exist before the early Pennsylvanian erosion interval, it is concluded that the oil migrated into this reservoir from Pennsylvanian source rocks.

Thin sand lenses in the basal Pennsylvanian marine conglomerate form a stratigraphic trap from which 18 tests are producing oil in the Beaver and Kraft-Prusa oil fields. These sand lenses were deposited on the flanks of the Beaver and Krier hills as shore-line sands at a time when these hills were islands in the transgressing Pennsylvanian seas.

Only one well is yielding oil from the pre-Cambrian quartzite itself, the Magnolia's Andrea No. 1, Sec. 7, T. 17 S., R. 10 W. (well 101, Pl. I). It is probable that fractures in the quartzite are providing the reservoir as the quartzite itself is practically non-porous.

A part of the dry holes drilled in the Kraft-Prusa district are also directly related to the buried pre-Cambrian hills. Such dry holes have been drilled within the Kraft-Prusa and Beaver fields at locations directly above the lower parts of the summits of the Beaver, Krier, Prusa, and Prusa North buried hills. (Examples on the cross sections, Plate I, include tests 22, 23, 40, 41, 42, and 87). The Penn-

TABLE V

List of Wells Illustrated in Cross Sections on Plate I

V

No.	Operator	Lease and Number	Spot	Sec. Twp. Rge.	Total Depth (Feet)	Potential (Bbls.) and Producing Zone
1	Gulf Oil Corp.	Redetzke 2	C NE NE	19-16S-11W	3328	3000 oil from Arbuckle dolomite
2	Sinclair Prairie	Schmidt 5	C NE NW NW	20-16S-11W	3428	498 oil and 5 water from Penn. ls.
3	Sinclair Prairie	Schmidt 1	C NE NE NW	20-16S-11W	3310	213 oil from Arbuckle residual sand in 1939, and 3000 oil from Penn. ls. in 1941
4	Sinclair Prairie	Oeser 1	C SE SE SW	17-16S-11W	3263	28½ MCF* gas from Penn. ls.
5	Sinclair Prairie	Oeser 3	C SW SW SE	17-16S-11W	3249	3000 oil and ½ MCF gas from Penn. ls.
6	Sinclair Prairie	Prusa 3	C NW NW NE	20-16S-11W	3314	449 oil and 150 water from Arbuckle residual sand in 1939, and 2953 oil from Penn ls. in 1941
7	Sinclair Prairie	Oeser 2	C SE SE SE	17-16S-11W	3426	19 oil in 8 hrs. from Penn. ls.
8	Sinclair Prairie	Redetzke 1	C SW SW SW	16-16S-11W	3312	151 oil from Arbuckle dolomite
9	Sinclair Prairie	Laudick 1	C NW NW NW	21-16S-11W	3305	3000 oil from Arbuckle dolomite
10	Herndon	Hitchman 1	C E½ NE NW	1-17S-12W	3382	Dry hole
11	Black-Marshall	Seyfert 1	C NE SE NE	36-16S-12W	3436	Dry hole
12	Skelly Oil Co.	Zorn 1	C NW NW	31-16S-11W	3275	61 oil and 12 water in 15 hrs. from Penn. ls.
13	Johnston	Oeser 1	C E½ NE SW	30-16S-11W	3293	328 oil and 10 MCF gas from Penn. ls.
14	Skelly Oil Co.	Esfeld 4	C W½ SW NE	30-16S-11W	3388	2128 oil from Penn. ls.
15	Skelly Oil Co.	Esfeld 7	C NW NE	30-16S-11W	3288	1986 oil from Penn. ls.
16	Black-Marshall	Redetzke 1	C SE SW SE	19-16S-11W	3360	265 oil from Arbuckle residual sand
17	Black-Marshall	Redetzke 2	C SE SE	19-16S-11W	3376	Dry hole
18	Shell Oil Company	Redetzke 1	C NE NE SE	19-16S-11W	3365	Dry hole
19	Gulf Oil Corp.	Redetzke 1	C SE SE NE	19-16S-11W	3341	1200 oil from Arbuckle dolomite
20	Isern & Pem	Laudick 1	C S½ SE NW	28-16S-12W	3385	Dry hole
21	Sharon	Norton 1	C S½ NE SW	21-16S-12W	3430	Dry hole
22	Darby Petr. Corp.	Stoskopf 1	C N½ NW NW	21-16S-12W	3369	Dry hole
23	Transwestern	Kultgen 1	C S½ SE SW	16-16S-12W	3362	Dry hole
24	Martin & Hearing	Kultgen B-1	C NE NE SE	17-16S-12W	3349	655 oil from Arbuckle residual sand
25	Martin	Kultgen 2	C SW SW NW	16-16S-12W	3360	807 oil from Arbuckle residual sand
26	Darby Petr. Corp.	Kultgen 4	C S½ N½ NW	16-16S-12W	3417	235 oil and 67 water from Arbuckle residual sand and Penn. chert conglomerate
27	Darby Petr. Corp.	Kultgen 2	C NE NE NW	16-16S-12W	3361	320 oil from Penn. sand
28	Darby Petr. Corp.	Jarus 3	C NW NW NE	16-16S-12W	3369	Dry hole
29	Black-Marshall	Maus 1	C E½ SW SE	9-16S-12W	3369	Dry hole
30	Pryor & Lockhart	Maus 1	C W½ SW NE	9-16S-12W	3428	Dry hole
31	Palmer	Polzin B-1	C NE SE SW	4-16S-12W	3357	Dry hole
32	Palmer	Polzin A-1	C NE NE SW	4-16S-12W	3338	1315 oil from Arbuckle dolomite
33	Darby Petr. Corp.	Casey 1	C SE SE NW	4-16S-12W	3400	Dry hole
34	Palmer	Casey 1	C SW SW NE	4-16S-12W	3330	1874 oil from Arbuckle dolomite
35	Palmer	Casey 2	C N½ S½ NE	4-16S-12W	3322	Dry hole
36	Bailey & Bailey	Galliart 1	C NE SE SW	34-15S-12W	3618	Dry hole
37	Stanolind Oil & Gas Co.	Oeser 1	C N½ SE SW	14-16S-12W	3345	490 oil from Arbuckle dolomite
38	Shell Oil Company	Riemann 1	C N½ NE NW	23-16S-12W	3461	1676 oil from Arbuckle residual sand
39	Gulf Oil Corp.	Minnie 4	C N½ SW NE	23-16S-12W	3358	616 oil from Arbuckle residual sand
40	Gulf Oil Corp.	Wells-Hofmeister 2	C N½ NW SE	23-16S-12W	3375	Dry hole
41	Black-Marshall	Veat 1	C NE NE NE	26-16S-12W	3395	Dry hole
42	Gulf Oil Corp.	Case 3	C NE SW NW	25-16S-12W	3311	Dry hole
43	Gulf Oil Corp.	Remmers 4	C NE SE NW	25-16S-12W	3337	321 oil and 53 water from Penn. ls.
44	Lauck & Moncrief	Oeser 4	C NE NW SE	25-16S-12W	3330	216 oil from Penn. ls.
45	Lauck & Moncrief	Oeser 3	C NE NE SE	25-16S-12W	3300	335 oil from Penn. ls.
46	Johnston & Pigott	Oeser 3	C N½ NW SW	30-16S-11W	3053	959 oil from Penn. ls.
47	Johnston	Oeser 2	C N½ SE NW	30-16S-11W	3035	3000 oil from Penn. ls.
48	Skelly Oil Co.	Esfeld 6	C E½ SW NE	30-16S-11W	3306	278 oil and 27 water from Penn. ls.
49	Skelly Oil Co.	Esfeld 5	C W½ SE NE	30-16S-11W	3326	3000 oil from Arbuckle residual sand
50	Skelly Oil Co.	Esfeld 1	C E½ SE NE	30-16S-11W	3320	435 oil and 58 water from Arbuckle residual sand
51	Gulf Oil Corp.	Joseph 1	C NW NW SW	29-16S-11W	3315	1633 oil from Arbuckle residual sand
52	Gulf Oil Corp.	Joseph 3	C E½ NW SW	29-16S-11W	3323	328 oil from Arbuckle residual sand
53	Gulf Oil Corp.	Joseph 4	C NE SE SW	29-16S-11W	3347	672 oil from Arbuckle sandy dolomite
54	Derby & Comanche	Dolochek 2	C NE NE NW	32-16S-11W	3353	50 oil from Arbuckle dolomite
55	Derby & Comanche	Dolochek 1	C NE SE NW	32-16S-11W	3348	1166 oil and 715 water from Arbuckle dolomite

No.	*Operator*	*Lease and Number*	*Spot*	*Sec. Twp. Rge.*	*Total Depth (Feet)*	*Potential (Bbls.) and Producing Zone*
56	Black-Marshall	Hitchman 3	C N½ NE SW	32-16S-11W	3358	402 oil from Arbuckle dolomite
57	Black-Marshall	Hitchman 1	C NE SE SW	32-16S-11W	3338	2759 oil from Arbuckle dolomite, and 5 MCF gas from Penn. ls.
58	Black-Marshall	Schneweis 2	C SW NE NW	5-17S-11W	3360	15 oil from Arbuckle dolomite
59	Black-Marshall	Schneweis 5	C NE SE NW	5-17S-11W	3358	213 oil and 14 water from Arbuckle dolomite
60	The Texas Company	Radenberg 1	C N½ SW NE	5-17S-11W	3397	Dry hole
61	The Texas Company	Radenberg 2	C SE NE	5-17S-11W	3351	106 oil from Arbuckle dolomite
62	Ash & Crown	Radenberg 2	C NE NE SE	5-17S-11W	3326	3000 oil from Arbuckle dolomite
63	Ash & Crown	Radenberg 1	C NE SE SE	5-17S-11W	3331	155 oil in 17 hrs. from Arbuckle dolomite
64	Ohio Oil Company	Riemann 1	C S½ SW SW	4-17S-11W	3338	360 oil from Arbuckle dolomite
65	Magnolia Petr. Co.	Grossardt 1-A	C N½ NE NW	9-17S-11W	3291	3000 oil from Arbuckledolomite
66	Magnolia Petr. Co.	Riemann 3	C S½ SW SE	4-17S-11W	3572	Salt water disposal well
67	Magnolia Petr. Co.	Riemann 1	C S½ SE SE	4-17S-11W	3297	3000 oil from Arbuckle dolomite
68	The Texas Company	Disque 9	C W½ SW SW	3-17S-11W	3637	Salt water disposal well
69	The Texas Company	Disque 6	C SE SW SW	3-17S-11W	3304	3000 oil from Arbuckle dolomite
70	The Texas Company	Disque 1	C SE SE SW	3-17S-11W	3344	1037 oil from Arbuckle dolomite
71	Shell Oil Company	Kroutwurst 2	C NE NE NW	10-17S-11W	3340	1623 oil and 33 water from Arbuckle dolomite
72	C. L. Price	Kraft 1	C SW NW NE	10-17S-11W	3288	1890 oil from Arbuckle dolomite. Discovery well of the Kraft-Prusa field. Completed May, 1937
73	Carter & Phillips	Kraft 7	C W½ NE NE	10-17S-11W	3276	3000 oil from Arbuckle dolomite
74	Carter & Phillips	Kraft 6	C E½ NE NE	10-17S-11W	3284	3000 oil from Arbuckle dolomite
75	Carter Oil Company	Hogan 3	C W½ NW NW	11-17S-11W	3355	394 oil and 764 water from Arbuckle dolomite
76	Carter Oil Company	Hogan 4	C E½ NW NW	11-17S-11W	3345	2113 oil and 642 water from Arbuckle dolomite
77	Cities Service Oil Co.	Hogan 3	C W½ NE NW	11-17S-11W	3361	3000 oil from Arbuckle dolomite
78	Cities Service Oil Co.	Hogan 4	C E½ NE NW	11-17S-11W	3430	Dry hole
79	Cities Service Oil Co.	Hogan A-5	C NE NW NE	11-17S-11W	3393	455 oil from Arbuckle dolomite
80	Cities Service Oil Co.	Hogan A-6	C NE NE NE	11-17S-11W	3415	448 oil from Arbuckle dolomite
81	Slick, Pryor, & Lockhart	Hogan 1-A	C SE NW	12-17S-11W	3500	Dry hole
82	Transwestern	Ehler 1	C E½ SE SW	12-17S-11W	3374	Dry hole
83	Transwestern	Fee 5	C W½ SW SE	12-17S-11W	3314	3000 oil from Arbuckle dolomite
84	Transwestern	Fee 3	C E½ SW SE	12-17S-11W	3306	3000 oil from Arbuckle dolomite
85	Transwestern	Fee 4	C W½ SE SE	12-17S-11W	3321	3000 oil from Arbuckle dolomite
86	Transwestern	Fee 2	C SE SE SE	12-17S-11W	3313	3000 oil from Arbuckle dolomite
87	Transwestern	Meyers 1	C SW NW NW	18-17S-10W	3306	Dry hole
88	Solar	Schartz 4	C SE NW NE	18-16S-11W	3268	1809 oil from Arbuckle dolomite
89	Solar	Schartz 3	C SE NE NE	18-16S-11W	3323	514 oil from Penn. ls.
90	Shell Oil Company	Oeser 3	C SW NW NW	17-16S-11W	3306	1296 oil and 530 water from Arbuckle dolomite
91	Shell Oil Company	Oeser 2	C NE SW NW	17-16S-11W	3316	1005 oil from Arbuckle dolomite
92	Champlin Refining Co.	Burmeister 2-B	C N½ SE SW	13-17S-11W	3035	Salt water disposal well
93	The Texas Company	Peterman 3	C N½ SW SE	13-17S-11W	3329	238 oil from Arbuckle dolomite
94	The Texas Company	Peterman 4	C N½ SE SE	13-17S-11W	3698	Salt water disposal well
95	Gulf Oil Corp.	Massman 1	C NW NW SW	18-17S-10W	3362	Dry hole
96	Fred Jones	Myers 1	C SW SW NW	18-17S-10W	3310	955 oil and 20 water from Arbuckle dolomite
97	Fred Jones	Myers 2	C NW SW NW	18-17S-10W	3314	1236 oil from Arbuckle dolomite
98	Magnolia Petr. Co.	Andrea 5	C SW SW SW	7-17S-10W	3333	361 oil from Penn. ls. in 1937 and 277 oil from Arbuckle dol. in 1941
99	Magnolia Petr. Co.	Andrea 6	C NW SW SW	7-17S-10W	3366	257 oil and 240 water from Penn. ls. in 1938, and 24 oil and 10 water from Arbuckle dolomite in 1941
100	Magnolia Petr. Co.	Andrea 3	C SW NW SW	7-17S-10W	3197	98 oil from Penn. ls.
101	Magnolia Petr. Co.	Andrea 1	C NW NW SW	7-17S-10W	3394	92 oil and 7 water from pre-Cambrian quartzite
102	Slick, Pryor, & Lockhart	Breford 1	C SW SW NW	7-17S-10W	3407	480 oil from Arbuckle dolomite. Discovery well of the former Breford (now Bloomer) field. Completed September, 1932
103	Slick, Pryor, & Lockhart	Breford 3	C NW SW NW	7-17S-10W	3405	Dry hole
104	Shell Oil Company	Brejoha 1	C NE SE NW	5-17S-10W	3458	Dry hole
105	Magnolia Petr. Co.	Schroeder 4	C SW NE	33-16S-10W	3320	103 oil and 3 water from Arbuckle dolomite
106	Magnolia Petr. Co.	Schroeder 3	C SE NE	33-16S-10W	3288	259 oil from Arbuckle dolomite
107	Cities Service Oil Co.	Schroeder C-3	C SW NW	34-16S-10W	3269	308 oil from Arbuckle dolomite
108	Cities Service Oil Co.	Schroeder C-1	C N½ NE NW	34-16S-10W	3307	292 oil from Arbuckle dolomite
109	Atlantic, Stanolind, & Gulf	Stoltenberg E-5	C S½ SW SE	27-16S-10W	3866	Salt water disposal well
110	Atlantic Refining Co.	Stoltenberg A-4	C N½ SE SE	27-16S-10W	3301	2020 oil from Arbuckle dolomite
111	Magnolia Petr. Co.	Schroeder 6	C E½ NW SW	26-16S-10W	3879	Salt water disposal well

Notes.—"Potential" is a well's official initial production for a 24-hour period. The Kansas Corporation Commission recognizes no potential greater than 3,000 barrels.

* MCF=1,000 cubic feet of gas.

sylvanian limestones failed to produce oil in these tests either because of inadequate porosity or because the porous zones were structurally a few feet too low and were water-bearing. The Pennsylvanian marine sand, the Cambro-Ordovician residual sand and the Arbuckle dolomite were absent at these locations.

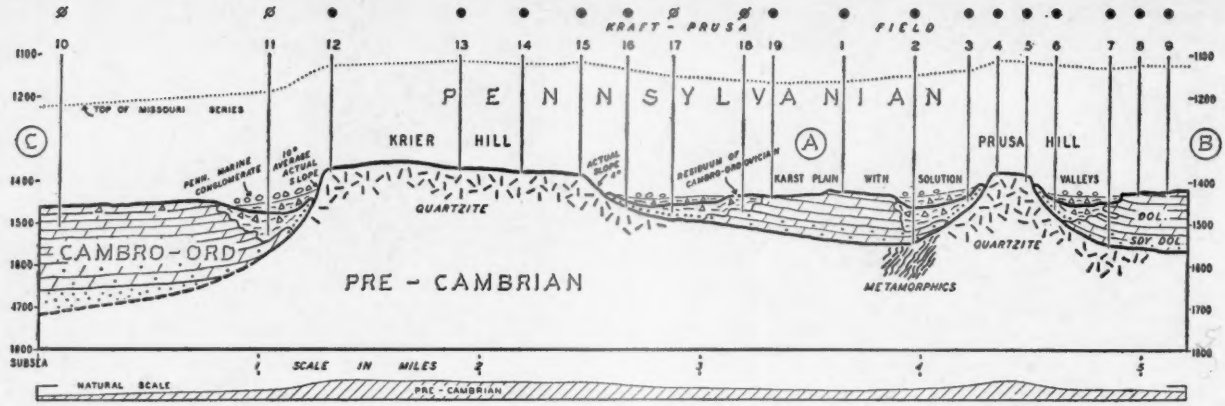
The majority of the dry holes in the Kraft-Prusa district are not, however, directly related to the buried hills, but are tests located above topographically low areas on the Cambro-Ordovician (Arbuckle) karst plain. Such dry holes may be located; (1) above the regionally low areas on this karst plain (examples on the cross sections, Plate I, are tests 10 and 20); (b) above the local depressions such as the sinkholes (examples are tests 33, 36, 78) and valley sinks (examples are tests 81, 82, 92, 94, 95); or (c) in the mid-part of the solution valleys (examples are tests 11, 17, 28 to 30). Largely due to the unpredictable vagaries of solution erosion, the ratio of dry holes to producing wells is exceptionally high; in all, 230 dry holes have been drilled in the Kraft-Prusa district in order to obtain the 504 oil wells which have yielded a cumulative production of about 25 million barrels of oil to January 1, 1946.[30]

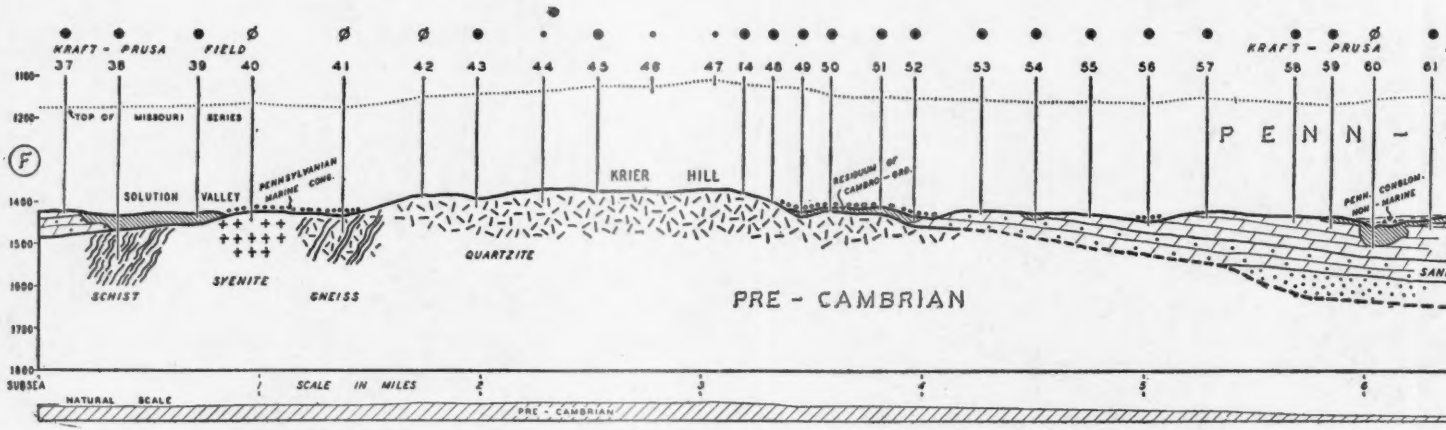
XI. Summary: Geologic History of Pre-Cambrian Hills

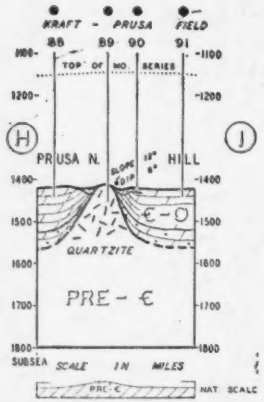
The vertical movements experienced by northeastern Barton County from late pre-Cambrian time to the present and the consequent status of the pre-Cambrian hills at various times in their geologic history are summarized in Figure 8. As described in the text of this report, it has been possible through study of the sedimentary rocks preserved on the flanks and above the summits of the buried pre-Cambrian hills to arrive at the following conclusions.

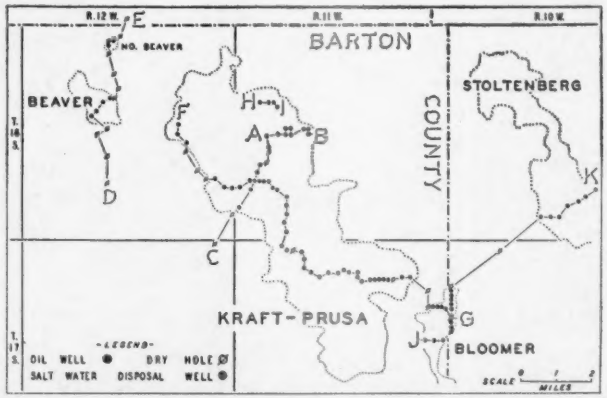
1. In late pre-Cambrian and most of Cambrian time these hills were monadnocks of resistant quartzite rising about 225 feet above the average surface of a peneplain eroded across a varied terrane of igneous and metamorphic rocks.
2. In early Cambro-Ordovician time these hills were gradually diminishing islands in the transgressing shallow Cambro-Ordovician seas.
3. In late Cambro-Ordovician time they were buried under 340 feet of dolomites, in part oölitic and cherty, deposited in these shallow seas.
4. In Ordovician time they were buried under 40 feet of Simpson shale and an estimated minimum of 100 feet of combined Viola and Maquoketa beds, or under a total sedimentary section of a minimum of 480 feet.
5. After extensive erosion in pre-Pennsylvanian and Pennsylvanian time the hills appear as "resurrected hills" rising about 25 feet above a peneplaned early Pennsylvanian land surface.
6. Following a rejuvenation of erosion due to uplift in early Pennsylvanian time the resurrected hills became fringed by solution valleys partially filled with continental sediments from which the early Pennsylvanian history of the hills can be deciphered.
7. In late Des Moines time the hills were islands in the transgressing Pennsylvanian seas.
8. In Missouri time they continued as gradually diminishing islands until inundated by the early Missouri seas.
9. By the end of Missouri time the hills were buried under 250 feet of sediments, largely limestones, part of which were shallow-water oölitic types.
10. Throughout Virgil time deposition continued so that by the close of Pennsylvanian time the hills were buried under 1,100 feet of upper Pennsylvanian rocks.
11. These hills have remained buried since Pennsylvanian time.
12. Their summits are now buried under 1,100 feet of Pennsylvanian beds, 1,700 to 1,800 feet of Permian beds, and 400 to 600 feet of Cretaceous beds, or under a total sedimentary section of approximately 3,300 feet.

[30] Note that these figures are for the Kraft-Prusa district as defined on page 2; hence, they include neither the dry holes mapped in T. 16 S., R. 10 W., nor the production from the Stoltenberg field.









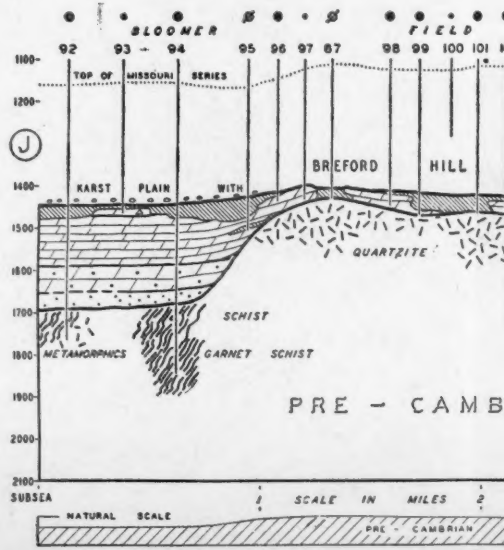
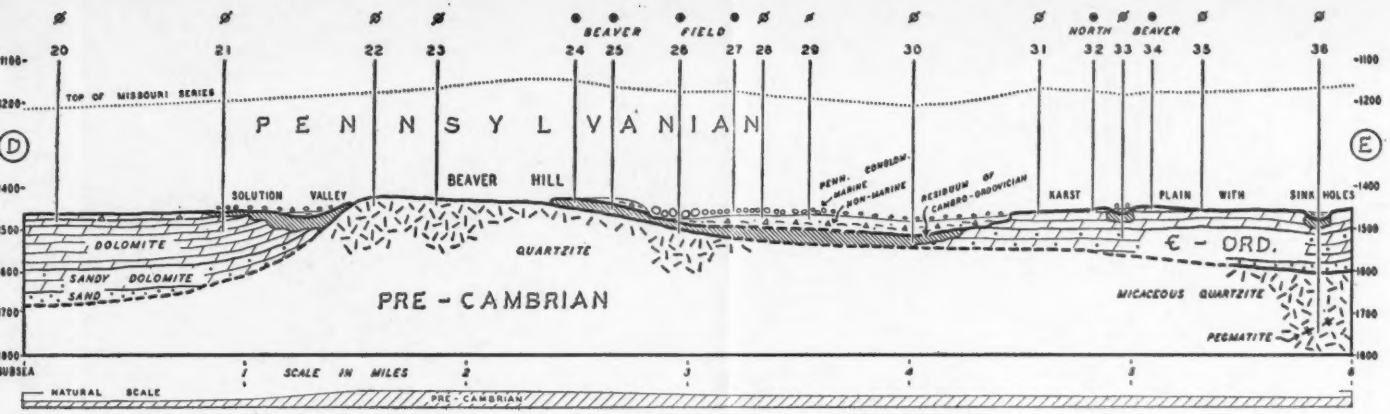
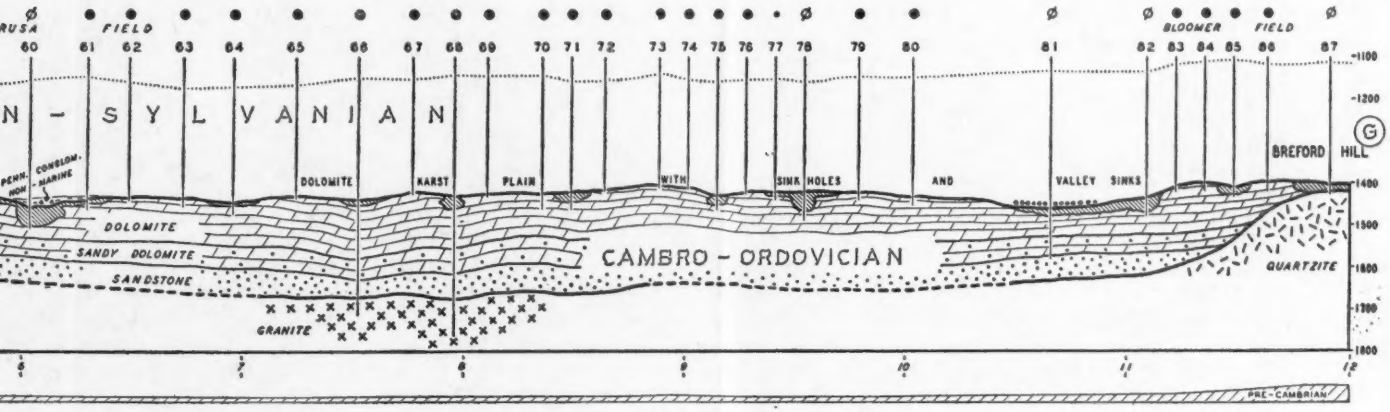
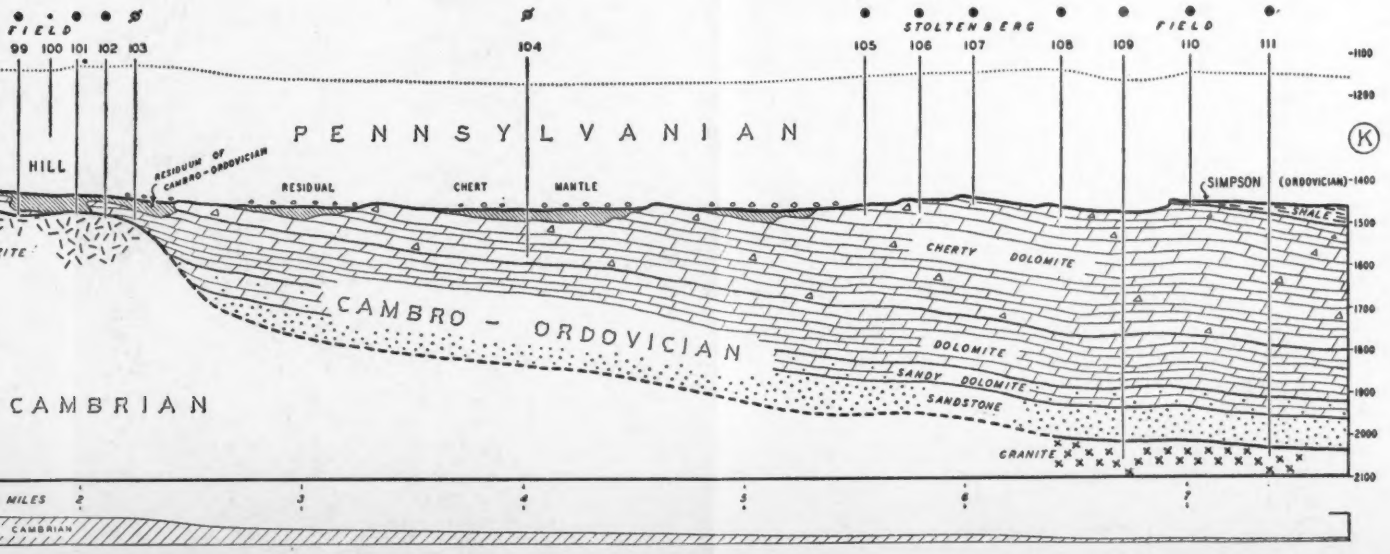


PLATE I. Cross sections. Vertical exaggeration ×10. Well numbers refer to Table V. Based on sample examination by Walters except for the eight tests indicated by the smaller well symbols. Wells No. 1 to No. 9 are repeated from Figure 4. For a detailed index map see Figure 2.


BEAVER
FIELD
NORTH BEAVER
20 21 22 23 24 25 26 27 28 29 30 31 32 33 34 35 36
TOP OF MISSOURI SERIES
PENNSYLVANIAN
D
E
SOLUTION VALLEY
BEAVER HILL
PENN. CONGLOM. MARINE NON-MARINE
RESIDUUM OF CAMBRO-ORDOVICIAN
KARST PLAIN WITH SINK HOLES
DOLOMITE
SANDY DOLOMITE
SAND
QUARTZITE
€ - ORD.
MICACEOUS QUARTZITE
PEGMATITE
PRE-CAMBRIAN
SCALE IN MILES
NATURAL SCALE
PRE-CAMBRIAN


FIELD
BLOOMER FIELD
60 61 62 63 64 65 66 67 68 69 70 71 72 73 74 75 76 77 78 79 80 81 82 83 84 85 86 87
N - SYLVANIAN
G
PENN. CONGLOM. MARINE NON-MARINE
DOLOMITE
KARST
PLAIN
WITH
SINK HOLES
AND
VALLEY SINKS
BREFORD HILL
DOLOMITE
SANDY DOLOMITE
SANDSTONE
GRANITE
CAMBRO - ORDOVICIAN
QUARTZITE
PRE-CAMBRIAN


FIELD
STOLTENBERG
FIELD
99 100 101 102 103 104 105 106 107 108 109 110 111
HILL
RESIDUUM OF CAMBRO-ORDOVICIAN
PENNSYLVANIAN
K
RESIDUAL
CHERT
MANTLE
SIMPSON (ORDOVICIAN)
SHALE
CHERTY DOLOMITE
CAMBRO - ORDOVICIAN
DOLOMITE
SANDY DOLOMITE
SANDSTONE
GRANITE
CAMBRIAN
MILES
CAMBRIAN

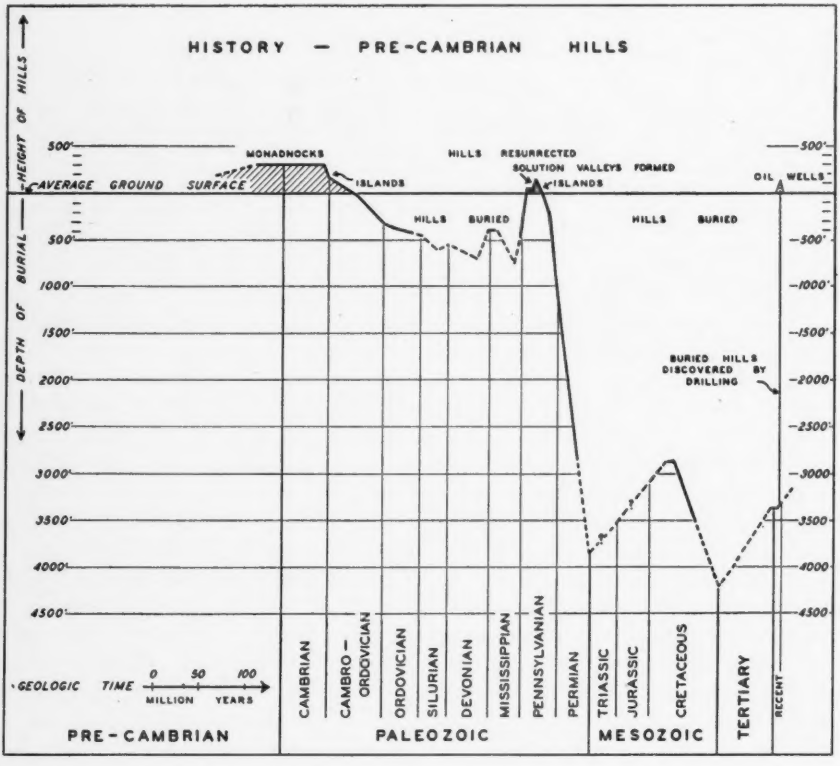


FIG. 8.—Graph of vertical movements experienced by pre-Cambrian hills in northeastern Barton County, central Kansas.

By a study of the regional setting of the buried hills, largely from the literature, it was possible to make reasonable estimates of the thicknesses of sedimentary rocks eroded from northeastern Barton County during the extensive erosional intervals represented by the important unconformities in Kansas at the base of the Mississippian, the base of the Pennsylvanian, the base of the Cretaceous, and the present land surface. It is thus possible to make the following deductions.

13. In Silurian and Devonian time "Hunton" beds, now entirely removed, of unknown thickness but of an estimated order of 200 feet may have been deposited above the hills so that they were probably buried beneath an estimated total of about 700 feet of pre-Mississippian rocks at the end of middle Devonian time.

14. Erosion in pre-Mississippian time removed the Silurian and Devonian beds from northeastern Barton County and probably also removed the post-Simpson Ordovician sediments, so that it may be estimated that at the beginning of Mississippian time the summits of the buried pre-Cambrian hills were only 380 feet below the average land surface.

15. Mississippian beds with an estimated thickness of 350 feet may have been deposited above these hills, so that at the end of Meramec time the hills were buried under a known 340 feet of Cambro-Ordovician dolomites and 40 feet of Ordovician shale plus an estimated 350 feet of Mississippian beds, or under an estimated total sedimentary section of about 750 feet, all of which was later removed by pre-Pennsylvanian and early Pennsylvanian erosion.

16. In Permian time an estimated 2,800 feet of Permian beds were deposited, 1,000 feet of which were removed by pre-Cretaceous erosion, so that at the end of Permian time the hills were buried under a known 1,100 feet of Pennsylvanian beds, a known 1,800 feet of Permian beds, and an estimated additional 1,000 feet of Permian beds, or under a total estimated sedimentary section of 3,900 feet.

17. An estimated 1,400 feet of Cretaceous beds were probably deposited above the hills, about 900 feet of which were removed by Tertiary and Recent erosion, so that at the end of Cretaceous time the hills were buried under a known 1,100 feet of Pennsylvanian, a known 1,800 feet of Permian, a known 500 feet of Cretaceous, and an estimated additional thickness of 900 feet of Cretaceous, or under an estimated total sedimentary section of 4,300 feet.

Since the relative position of the pre-Cambrian hills described in this report can be stated quantatively with reference to the average ground surface during each of these seventeen events in their history, the relative position of these hills can be plotted graphically as in Figure 8. Geological time (from estimates compiled by Elias[31]) is plotted to scale as abscissas and the height of the hills above the average ground surface at any given time, or their depth of burial below it, is plotted as an ordinate. When such plotted points are connected the resulting space-time curve depicts the vertical component of the movements to which the buried pre-Cambrian hills were subjected. Such movements are of fundamental importance and bear a causative relationship to a number of consequent factors which could be plotted on similar coordinates if data were available, such as, the position and rate of change of sea-level at various times, the depths of the seas during inundations, the thickness and lithologic character of the sediments deposited, the amount and rates of erosion, and the depths of burial of oil in the several reservoir rocks at various times. It is through the study of such of these consequent factors as could be analyzed (principally the lithologic character of the sediments deposited) that this fundamental curve was derived which epitomizes what is known of the geologic history of the buried pre-Cambrian hills in the Kraft-Prusa district of northeastern Barton County, central Kansas.

[31] Maxim K. Elias, "Geologic Calendar," *Bull. Amer. Assoc. Petrol. Geol.*, Vol. 29, No. 7 (July, 1945), Table I, p. 1038.

BULLETIN OF THE AMERICAN ASSOCIATION OF PETROLEUM GEOLOGISTS
VOL. 30, NO. 5 (MAY, 1946) PP. 711-729 14 FIGS.

GEOLOGICAL NOTES

VICK FORMATION OF PRE-TUSCALOOSA AGE OF ALABAMA COASTAL PLAIN[1]

LOUIS C. CONANT[2]
Tuscaloosa, Alabama

The oldest formation of the Coastal Plain heretofore recognized on the outcrop in the eastern Gulf region is the Cottondale formation of the Tuscaloosa group[3,4] of Upper Cretaceous age, though oil test wells 30 and more miles downdip from the inner edge of the Coastal Plain consistently encounter at least several hundred feet of Lower Cretaceous or Jurassic strata. Because of such thicknesses of these strata so near the outcrop, many geologists have thought that Coastal Plain beds of pre-Tuscaloosa age should reach the surface somewhere in central Alabama. Recently, while engaged in a study of the Tuscaloosa group, the writer found several outcrops of semi-indurated sandstone and mottled brick-red and gray sandy clay unlike and apparently older than anything known in the Tuscaloosa but younger than the near-by Paleozoic rocks. As these outcrops are near the small community of Vick, about 4 miles east of Centerville, Bibb County, it is proposed that the strata represented by these outcrops be provisionally designated the Vick formation, of either Jurassic or Lower Cretaceous age, until such time as they can be correlated with some well established subsurface formation.

These outcrops are present along and near Alabama Highway 6, about 40 miles southeast of Tuscaloosa and 60 miles northwest of Montgomery. The accompanying map shows all the observed outcrops of the Vick formation. These outcrops indicate an inlier of less than 1 square mile, in the valley of Sandy Creek, but probably the formation is present under the alluvium and terrace cover in a considerably greater area. The nearest known outcrops of Paleozoic rocks are at Garey Springs, 1½ miles north, and in the Cahaba River valley at Centerville about 4 miles west. Between Vick and Garey Springs is a ridge of high hills composed of sand and clay belonging to the Eoline and Coker formations of the Tuscaloosa group, and between Vick and Centerville the valley of Sandy Creek has beds of glauconitic sand and clay of the Eoline formation extending down to the

[1] Manuscript received, March 14, 1946. Published by permission of the director of the Geological Survey, United States Department of the Interior.

[2] Geologist, Geological Survey.

[3] L. C. Conant, and W. H. Monroe, "Stratigraphy of the Tuscaloosa Group in the Tuscaloosa and Cottondale Quadrangles, Alabama," *U. S. Geol. Survey Oil and Gas Inves. Prelim. Map 37* (1945).

[4] W. H. Monroe, L. C. Conant, and D. H. Eargle, "Pre-Selma Upper Cretaceous Stratigraphy of Western Alabama," *Bull. Amer. Assoc. Petrol. Geol.*, Vol. 30 (February, 1946), pp. 187–212.

mile-wide floodplain. At Centerville, sand of probable Tuscaloosa age rests on folded Paleozoic rocks.

In spite of the limited area of exposure of the Vick formation, several of the outcrops have between 20 and 50 feet of beds, and fragmentary sections can be readily matched to show that a total thickness of about 100 feet of beds is represented. The type locality is designated as a series of exposures along 0.4 mile of the

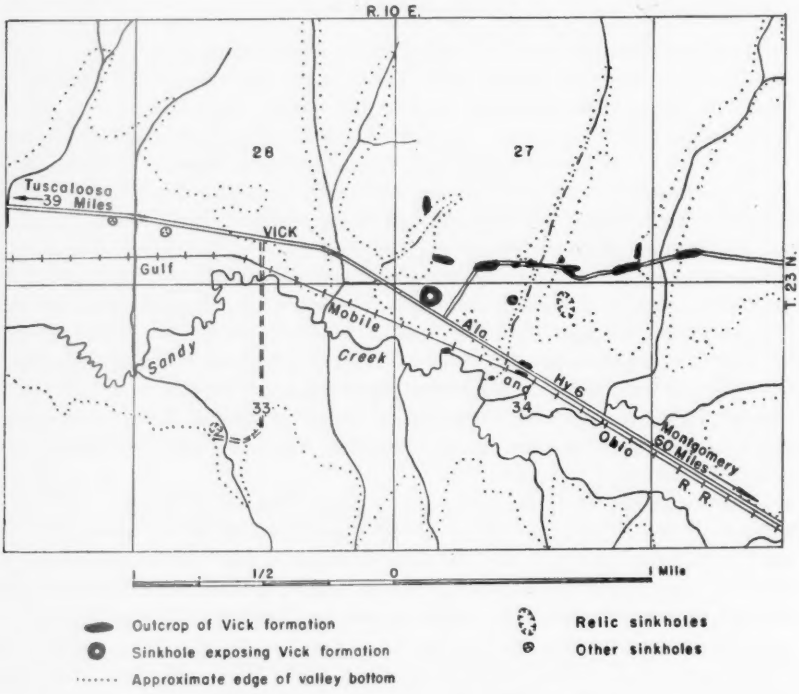


FIG. 1.—Map showing outcrops of Vick formation in vicinity of Vick, Bibb County, Alabama.

old Centerville-Randolph road in the SE. $\frac{1}{4}$, SW. $\frac{1}{4}$, and the SW. $\frac{1}{4}$, SE. $\frac{1}{4}$ of Sec. 27 T. 23 N., R. 10 E., together with exposures in the wall of a 60-foot sinkhole $\frac{1}{4}$ mile southwest of the road exposures.

In the sinkhole which is at the north edge of Highway 6, 9 feet of incompletely indurated fine clayey sandstone is exposed just above water level on the north side and is overlain abruptly, but in apparent conformity, by about 40 feet of slightly indurated compact sandstone which is coarse-grained, micaceous, locally gravelly, and somewhat clayey. Above this sandstone locally is laminated

clay, 2 to 3 feet thick, probably of Eoline age, and this is overlain by 10 to 20 feet of terrace sand and gravel. Careful search of the walls reveals no signs of the strata having been disturbed by the sinkhole collapse. The pond in the sinkhole is reported to be about 20 feet deep and its present water level is about 25 feet lower than the level of Sandy Creek $\frac{1}{4}$ mile south.

The westernmost outcrop of those along the east-west road, about $\frac{1}{4}$ mile northeast of the sinkhole, shows, at the base, 3 feet of sandstone like that in the upper part of the sinkhole. This sandstone grades upward, through a 3-foot transition zone, into 12 feet of brick-red, lavender, and gray sandy clay. This clay is overlain by about 15 feet of gray and reddish clay which may be part of the Vick formation though exposures are too poor to determine its relationships. The 12-foot bed of brick-red clay has a peculiar mottled appearance due in part to abundant borings or tubes of undetermined origin. Many geologists who have seen this mottled brick-red clay have expressed the opinion that it resembles clay of Lower Cretaceous or Jurassic age in many of the oil test wells. A few hundred feet east, two other outcrops show the coarse compact sandstone from 4 to 18 feet lower than that at the base of the outcrop just described.

At the O. E. Reeves farm, about 600 feet farther east, an abandoned part of the old road, just north of the present one, shows the only known well exposed upper contact of the Vick formation. Here 13 feet of medium to coarse strongly cross-bedded micaceous light gray semi-indurated sandstone grades upward into about 16 feet of fine cross-bedded micaceous and argillaceous sand which, at the top, resembles the transitional zone below the brick-red clay in the road outcrop 0.4 mile west. The brick-red clay is missing here, however, apparently because it was eroded before deposition of the Tuscaloosa beds, and the fine sand is overlain unconformably by a coarse conglomeratic sandstone believed to be the base of the Eoline formation, which here is at the base of the Tuscaloosa group. This coarse upper sandstone forms a conspicuous ledge which tapers within a distance of about 100 feet from a thickness of 6 feet to a feather edge and is overlain by a fissile clay which contains leaf impressions and in which Mrs. Esther Applin[5] has found a few Foraminifera somewhat similar to those found in the outcropping Lewisville beds of Texas. In addition to the 29 feet of pre-Tuscaloosa beds exposed in the old road, Mr. Reeves reports that a 65-foot well near his house and just north of the old road was dug with pick and axe in material similar to the 13 feet of coarse sandstone at the base of the road outcrop. This well starts 10 feet above the base of the road outcrop, thus adding 55 feet to the 29 feet visible in the old road. As the 12 feet of brick-red clay at the west end of the road is not present at this exposure, it may be inferred that the total thickness of the Vick beds present in the region is at least 95 feet.

At the west edge of a small floodplain about $\frac{1}{4}$ mile southwest of the Reeves residence is a small sinkhole, locally known as the "black sink." It is about 35 feet in diameter at the top, 20 to 30 feet deep, and its sheer walls of coarse semi-

[5] Personal communication.

indurated sandstone recede at the base as much as 15 feet. The water level in the bottom of this sinkhole is about 15 feet below the nearby stream ditch which is dry most of the time in spite of a good flow of water a mile north upstream.

Several other small sinkholes are present in the area and it is common for parts of fields to fall in, leaving holes from 5 to 15 feet in diameter, and a few feet deep. Limestone is obviously not far below the surface, as would be expected from a study of the 1926 Geologic Map of Alabama which shows thick beds of limestone of early Paleozoic age trending directly toward the Vick locality, but so far as known no wells in the vicinity of Vick encounter limestone, though sandstone of the Vick formation is encountered in many places.

Careful consideration was given to the possibilities that the sandstone and clay of the Vick formation may be Paleozoic or Upper Cretaceous in age, but it is concluded that it can be neither, for the reasons here set forth.

It has been suggested that the brick-red clay resembles the weathered shale of the Rome formation (Cambrian), but near-by outcrops of the Rome are highly folded, the structure is preserved in the weathered material, and thin beds of calcareous sandstone are present. As the clay of the Vick formation clearly grades downward into flat sandstone, and neither the sandstone nor clay shows evidence of folding or metamorphism, it is evident that the Vick is not a part of the Rome formation.

The semi-indurated sandstone somewhat resembles weathered sandstone of the Pottsville formation (Pennsylvanian), but in such exposures the disintegrated sandstone of the Pottsville is commonly only about 5 feet thick and grades downward into characteristic solid gray sandstone. The sandstone of the Vick formation is everywhere only semi-indurated at most, even at the base of the 50-foot outcrop in the big sinkhole and in the bottom of the 65-foot well on the Reeves farm. Some geologists have suggested that if sandstone of the Pottsville formation lay immediately above limestone the percolating waters might disintegrate such a thickness of sandstone as is here present, though that seems unlikely. The sandstone is unlike anything seen in the Pottsville, and grades upward into the brick-red clay. A more compelling objection to a possible Pottsville age of the sandstone and clay of the Vick formation is a consideration of the regional structure of the Palezoic rocks. A glance at the Geologic Map of Alabama shows that highly folded and faulted rocks ranging in age from Cambrian to Mississippian trend directly toward Vick; and these rocks are present as close as 1½ miles north, though they are not so shown on the map. In the near-by Cahaba coal field the Pottsville rocks are involved in the folding and faulting. It is unbelievable that within 1½ miles along the strike this highly folded structure should give way to undisturbed beds, nor is it much more likely that a thrust sheet of Pottsville rocks forms a thin layer over the limestone which obviously is only a short distance below the surface.

The possibility that the sandstone and clay of the Vick formation may be

of Tuscaloosa age is to be taken much more seriously; indeed E. A. Smith[6] in the 1890's so identified the outcrop at the eastern end of the proposed type locality, though it is doubtful whether the sandstone was at that time as well exposed as it is to-day. In the Survey's recent stratigraphic study of the Tuscaloosa group along the strike for more than 100 miles and in several shallow wells[7] down the dip no materials were seen near the base of the Tuscaloosa group that much resemble the semi-indurated sandstone or the brick-red mottled clay. The sandstone and the clay, on the other hand, are strikingly similar to core and cutting samples in the pre-Tuscaloosa parts of oil test wells a few tens of miles down the dip—samples to which are commonly assigned a Lower Cretaceous or Jurassic age. Some miles west and northwest the basal beds of the Tuscaloosa group are apparently non-marine unconsolidated sand and clay of the Cottondale formation, and these are overlain by glauconitic sand and clay of the Eoline formation, but in the region east of Centerville the Cottondale formation seems to be almost or entirely missing on the outcrop except in some of the low places on the irregular pre-Tuscaloosa surface. Fragmentary evidence suggests that the inlier of the Vick formation is in reality an ancient hill on the pre-Tuscaloosa surface—a hill that has been partially uncovered in the Sandy Creek valley. The induration which characterizes all outcrops of the sandstone suggests that the formation has had a quite different history than have the younger beds of the Coastal Plain.

As very little is known of the stratigraphic relations of the Lower Cretaceous and Jurassic beds in the eastern Gulf region, there is no satisfactory basis for determining whether the Vick formation is Lower Cretaceous or Jurassic in age. The recent discovery of a thick section of salt and anhydrite of the supposed Eagle Mills formation (Jurassic) in the Southern Natural Gas Company's Morgan well No. 1 in Wilcox County, Alabama, only 75 miles downdip from Vick, indicates the definite possibility that Jurassic beds may extend to the outcrop. On the basis of published descriptions by Weeks,[8] Imlay,[9] and Swain,[10] as well as opinions expressed by several geologists who have visited the Vick exposures, it seems most likely that the Vick formation belongs to the Cotton Valley group of Upper Jurassic age.

[6] E. A. Smith, L. C. Johnson, and D. W. Langdon, Jr., "Report on the Geology of the Coastal Plain of Alabama," *Geol. Survey Alabama* (1894), section (m) on p. 336.

[7] D. H. Eargle, "Correlation of the Pre-Selma Upper Cretaceous Formations Between Tuscaloosa County, Alabama, and Neshoba County, Mississippi," *U. S. Geol. Survey Oil and Gas Inves. Prelim. Chart 20* (1946).

[8] W. B. Weeks, "South Arkansas Stratigraphy with Emphasis on the Older Coastal Plain Beds," *Bull. Amer. Assoc. Petrol. Assoc.*, Vol. 22 (August, 1938), pp. 953–83.

[9] R. W. Imlay, "Lower Cretaceous and Jurassic Formations of Southern Arkansas and Their Oil and Gas Possibilities," *Arkansas Geol. Survey Infor. Cir. 12* (1940).

[10] F. M. Swain, "Stratigraphy of Cotton Valley Beds of Northern Gulf Coastal Plain," *Bull. Amer. Assoc. Petrol. Geol.*, Vol. 28 (May, 1944), pp. 577–614.

"JACOB STAFF" AND MEASUREMENTS OF STRATIGRAPHIC SEQUENCES[1]

(Theoretical treatment)

J. A. BROGGI[2]
Lima, Peru

Under the title "New Technique for Measurement of Stratigraphic Units," Bernhard Kummel, Jr., published a paper in this *Bulletin* (Vol. 27, No. 2 (February, 1943), pp. 220–23; 1 fig.), suggesting an inexpensive "Jacob staff" and clinometer in place of a Brunton compass attached to a rod as employed before.

As only one particular case is treated in Kummel's paper, it may be useful to describe and explain the theory of all cases that may be encountered in the field. The field conditions for the measurement of stratigraphic thicknesses vary according to the slope of the ground and dip of the strata. Under these variable conditions are the following divisions.

Ground	*Strata*
A. Horizontal	1. Horizontal 2. Inclined 3. Vertical
B. Inclined	1. Horizontal 2. Inclined 3. Vertical
C. Vertical	1. Horizontal 2. Inclined 3. Vertical

A. Horizontal ground.—We make our measurements on a horizontal plane on which the strata crop out. In this case the Jacob staff technique, especially the Kummel design, integrated by a quadrant clinometer attached to a rod or staff at its end, can be used as follows.

1. Horizontal strata.—In this case only one stratum surface crops out on the ground and it is therefore impossible to determine the thickness of the underlying bed or sequence.

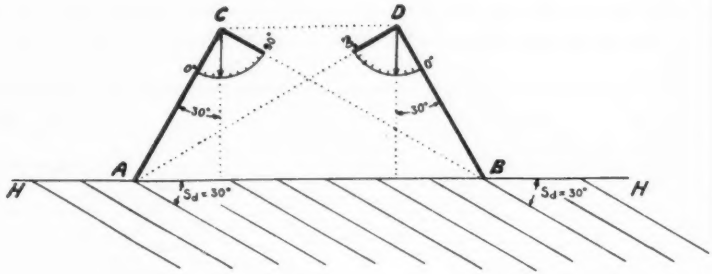
2. Inclined strata.—In order to obviate difficulties, make the measurements with the Jacob staff in a bearing normal to the strike of the strata. The section of Figure 1 is in that bearing, and we can see that it is possible to measure the thickness in two directions: from A to B and from B to A. In this case, as in all the following cases, the length of the Jacob staff equals the thickness of the measured strata. Whatever the direction of the measurement, the clinometer angle reading should be equal to the stratum dip S_d, that is, 30° in Figure 1.

3. Vertical strata.—It is clear that if the strata are normal to the surface, all

[1] Manuscript received, March 20, 1946.

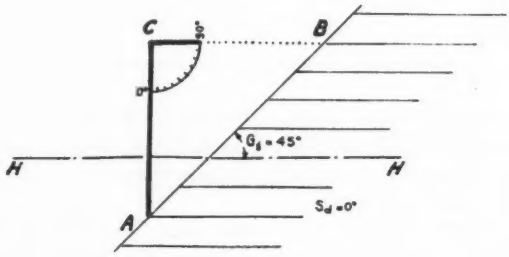
[2] Director, Instituto Geological del Perú; secretary, Sociedad Geologico del Perú. The writer desires to acknowledge the assistance of Robert G. Yates, of the United States Geological Survey in offering suggestions and revising the English.

Fig. N° 1



S_d = Strata dip

Fig. N° 2

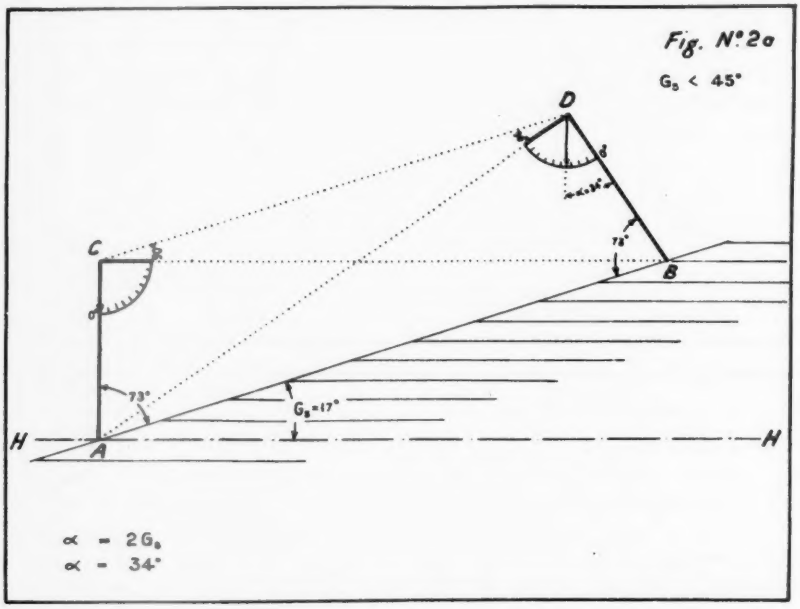


G_s = Ground slope
S_d = Strata dip

horizontal measurements taken normal to the strike will be the real thickness. It is not then necessary to use the clinometer, and the staff itself can be employed as a meter stick.

B. Inclined ground.—The more common cases are included here.

1. Horizontal strata.—Figure 2 shows that in climbing the slope it is only necessary to put the clinometer in 0° or vertical. The measurement can also be made descending the slope, giving backsights only and finding a good position



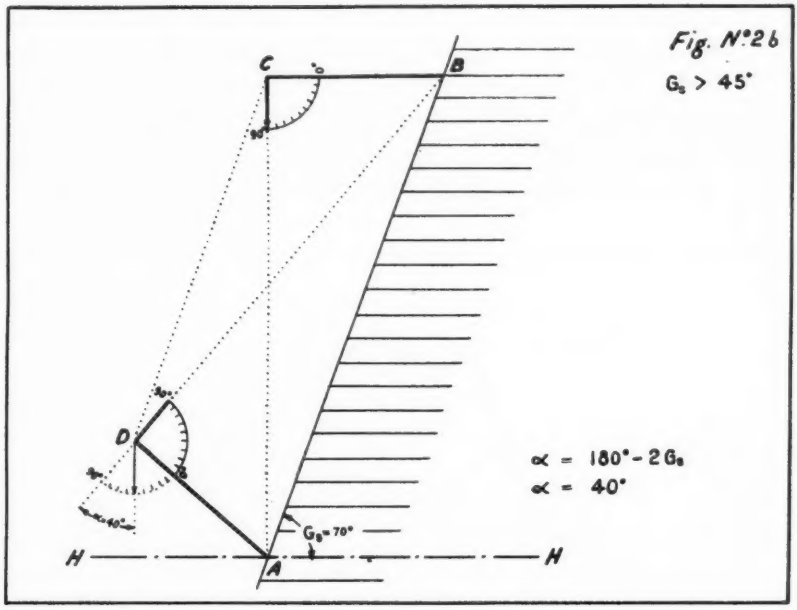
for the rod by trial and error; also by computing a different position according to a dial angle α deducted geometrically, the value of which is shown in Figures 2a and 2b in cases where the ground slope is less or more than 45°, respectively. For 2b cases, a 180° dial is necessary.

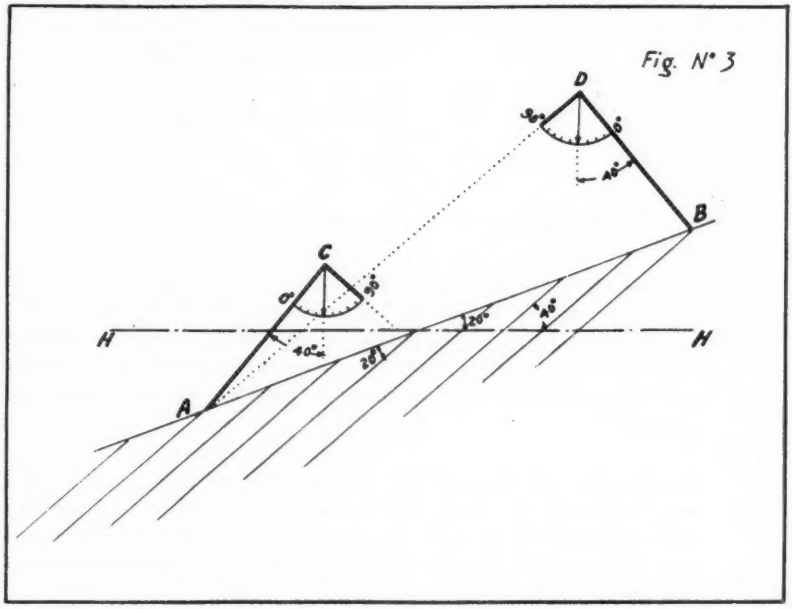
2. Inclined strata.—There can be two cases: (a) when the slope and strata are dipping in the same direction, and (b) when the slope and strata dip in opposite directions.

a. *Dips of the ground slope and the strata dip are in the same directions.*—

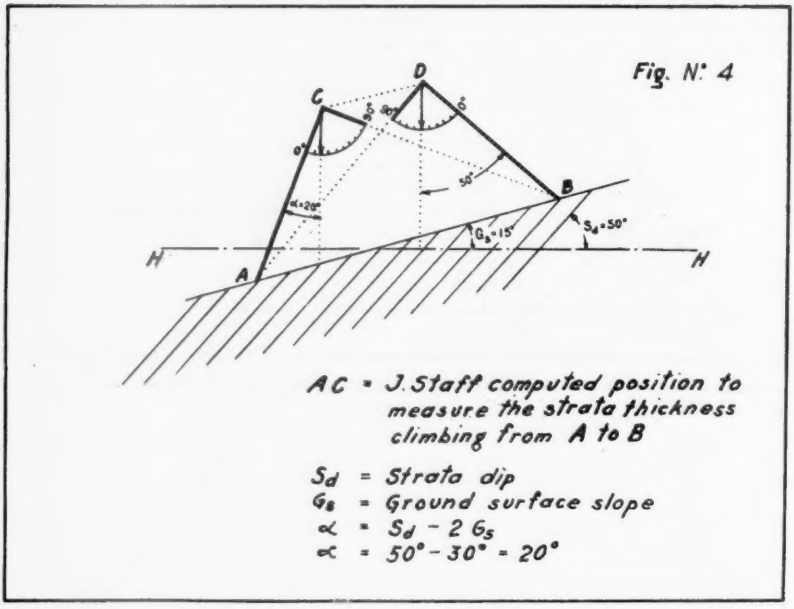
Three divisions must be considered:

a_1. *Ground slope and the strata are parallel.*—No measurements are possible as explained in case A1.


Fig. N°2b
$G_s > 45°$
C
B
D
A
H
H
$\alpha = 180° - 2G_s$
$\alpha = 40°$
$G_s = 70°$

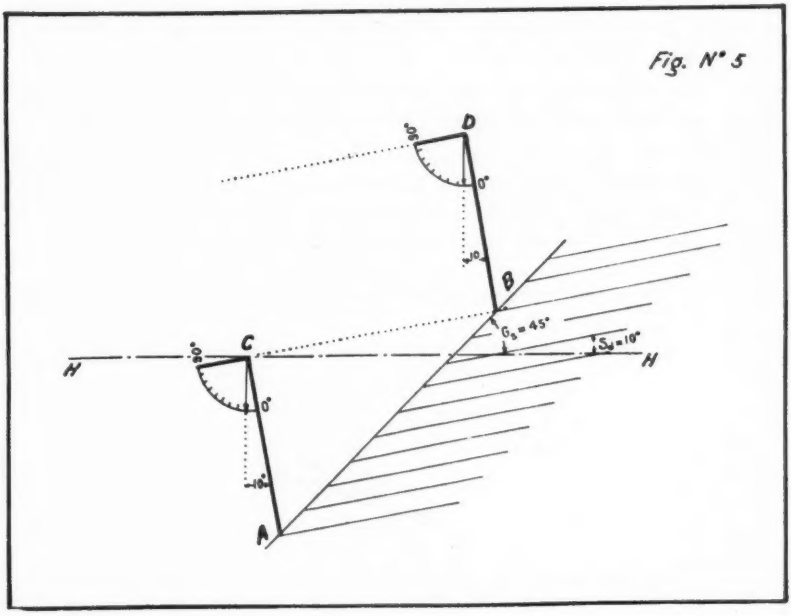

Fig. N° 3
D
B
C
A
H
H
40°
20°
45°

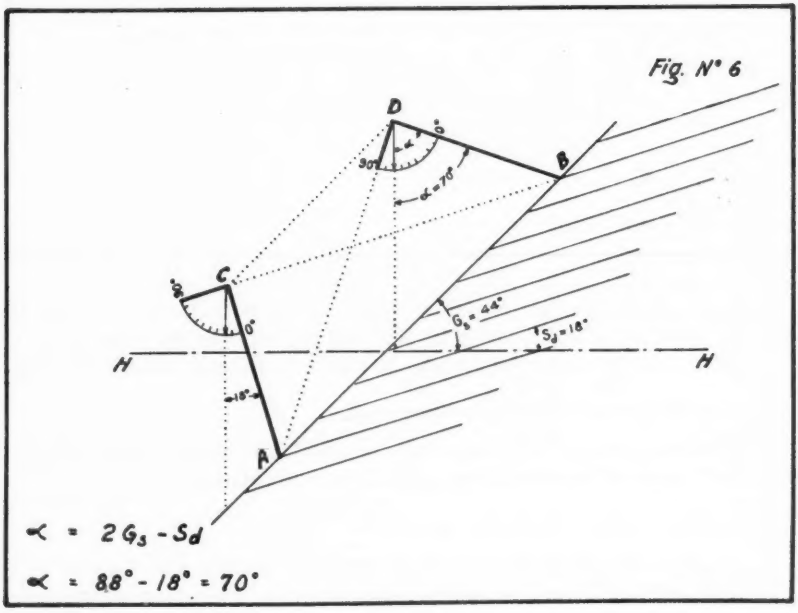
a_2. *The slope and the strata are dipping divergently downslope.*—This case is illustrated in Figure 3, and it can be seen that the Jacob staff can be used only in going downslope, that is, from *B* to *A*. But Figure 4 and Figure 1 both show that it is not always necessary to place the staff normal to the bedding planes. Other positions in reverse directions, which make the same angle with the ground slope fill the same function. In Figure 1, the clinometer reads the same in both positions of the staff



and also reads an angle equal to the dip of the strata because the two equal triangles have a common horizontal base; but in Figure 4 the base is inclined; therefore, the inclination of the staff not normal to the strata dip must be geometrically computed from the slope and the strata dips and values deducted for the clinometer angle as explained in the same drawing.

a_3. *The slope and the strata are convergent downslope.*—Figure 5 shows that in this case the Jacob staff can be used only with *AC* reversing or with a supplementary (180°) dial by climbing the slope. Figure 6 shows that the computed position *BD* can be used with a quadrant dial (90°) and only in a descending direction.

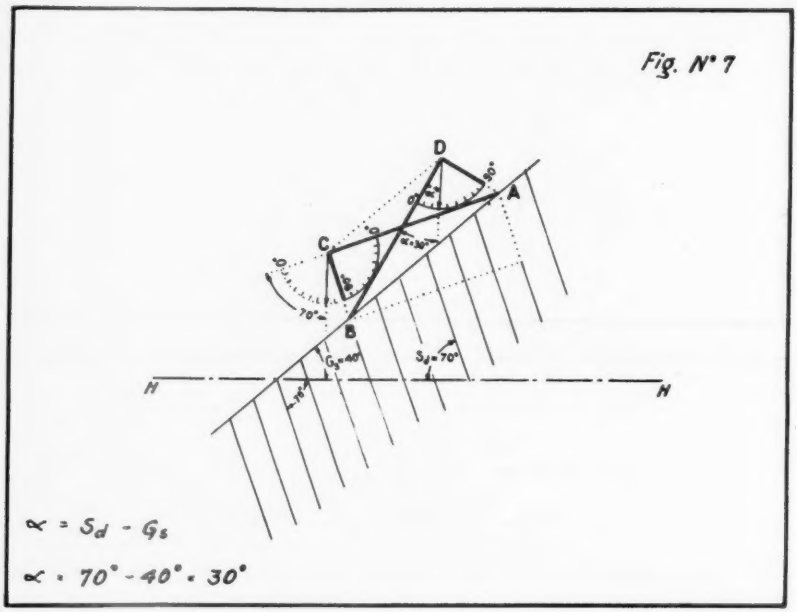

Fig. N° 5
D
B
C
A
H
H
$G_s = 45°$
$S_d = 18°$


Fig. N° 6
D
B
C
A
H
H
$G_s = 44°$
$S_d = 18°$
$\alpha = 2G_s - S_d$
$\alpha = 88° - 18° = 70°$

b. Dips of the ground slope and the strata dip are in opposite directions.—Three cases are involved.

b_1. *When the dip and slope are perpendicular to each other.*—The clinometer is not used and the staff only is employed like a meter stick.

b_2. *The dip and slope form an angle less than 90°.*—Figure 7 shows that by locating the rod normal to the bedding planes and by using a supplementary dial, we only can measure the thickness descending *AC*. The computed position is *BD*, and its clinometer angle α is given.



b_3. *The strata dip and slope make an angle of more than 90°.*—This is the favorable case considered by Kummel (*op. cit.*, Fig. 1). Descending, we can use the computed angle α. In Figure 8, we have deducted its value.

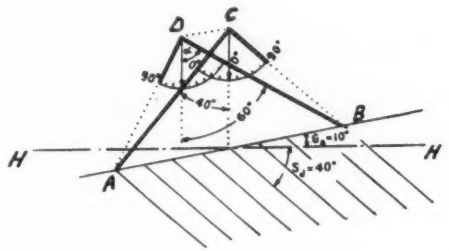
C. Vertical ground.—There are three cases.

1. Horizontal strata.—The slope being perpendicular to the ground the rod is used like a meter stick as in similar cases of perpendicularity.

2. Inclined strata.—There are two cases.

a. *The strata and ground slope are divergent downward.*—Figure 9 shows that it is possible to use the Jacob staff normally in descending by employing

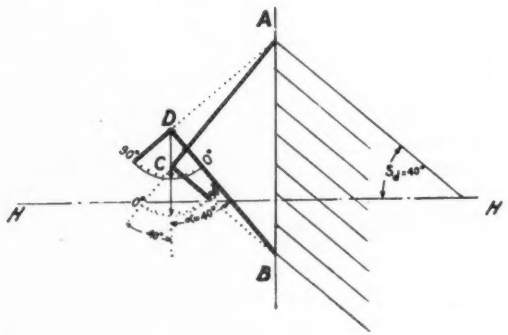
Fig. N.° 8



$\alpha = 2G_s + S_d$

$\alpha = 20° + 40° = 60°$

Fig. N° 9



$\alpha = S_d$

$\alpha = 40°$

Fig N° 10

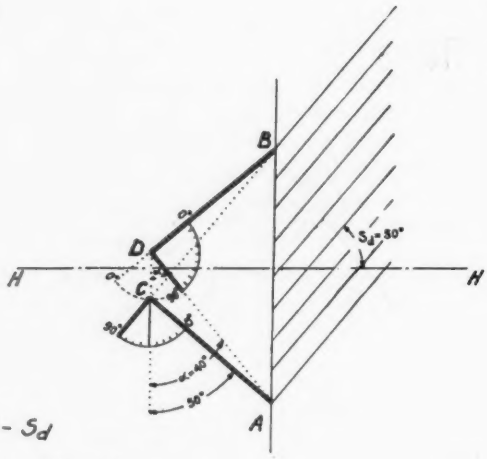
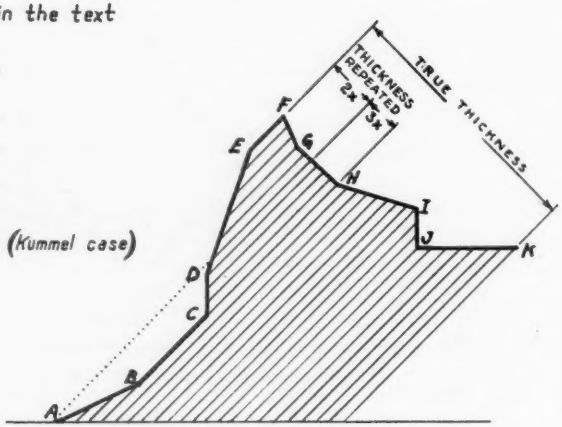


Fig. N° 11

Cases treated in the text

AB	B 2 a_2
BC	B 2 a_1
CD	C 2 b
DE	B 2 a_3
EF	B 2 a_1
FG	B 2 b_2
GH	B 2 b_1
HI	B 2 b_3 (Kummel case)
IJ	C 2 a
JK	A 2



a supplementary dial. A computed position and a reversed dial are necessary when climbing.

b. *The strata are convergent downslope with the ground slope.*—As shown in Figure 10, we can measure in climbing by reversing the quadrant dial and reading the starta dip directly. Descending, we can only use a supplementary dial and a computed position which angle value α is complementary to the strata dip.

3. *Vertical strata.*—This is a case of parallelism between ground and strata in which it is impossible to measure any thickness.

Measurement of a great thickness.—It has been stated before that the Jacob staff has advantages over other methods when measurements are taken on the strata dip direction, but where the attitudes of the beds are changing we must change the dial angle, otherwise the rod will not be normal to the bedding planes. It has not been pointed out before that this method has other limitations according to the relations of ground and strata. At the same time we have presented here the possibilities of making measurements with a computed position for the rod not normal to the bedding planes and of reversing the quadrant dial or using a 180° dial. These special solutions here described will be useful when the operator has to measure a thick sequence with changing dips across variable slopes.

The necessity of taking notes on the changes of the strata dip has already been stated (Kummel, *op. cit.*), but it is also necessary to note carefully changes of the ground slopes because we may often be in the presence of a new case which requires a different solution.

Figure 11 shows a profile across a sequence with points marked to show where a change in technique of measurement is necessary.

Conclusions.—The use of the Jacob staff, as stated here, is not a simple matter. There are many limitations according to the strata and ground dips. All cases are considered here and given the mathematical solutions. In measuring a big sequence, it is necessary to draw a profile sketch, in which we fix the points of changing strata or ground dips and so avoid any duplication of measures.

SOME DEVELOPMENTS IN AERIAL PHOTOGRAPHY DURING THE WAR[1]

L. E. NUGENT, JR.[2]
Fort Worth, Texas

The great emphasis placed on aerial photography and photographic interpretation in the past 5 years is difficult to appreciate except for those directly concerned with the war effort. For tens of photographs taken in the pre-war years, thousands have been taken during the war years. This vast increase resulted from the urgent need for accurate intelligence data, charts, and maps and was made

[1] Manuscript received, March 27, 1946. This paper was released by the United States Navy.

[2] Box 1720.

possible by the remarkable surge of American airpower. Such an increase can not fail to have a profound influence on the relation of post-war aerial photography to geology.

The mechanical improvement and availability of aircraft suitable for photographic reconnaissance and mapping will be a major factor. Although it is illogical that commercial photography should utilize the heavy-bombardment type of aircraft employed on long military missions or the fast single-seat fighter on low-altitude "dicing" missions, there is little question but that the increased range, ceiling, stability, and safety of post-war aircraft will improve commercial photographic standards as well as open new fields to photography. Further, the thousands of pilots, photographers, and air-crewmen trained by the services will undoubtedly provide adequate and satisfactory personnel.

Cameras, negative and positive stocks, and processing equipment have improved too. The large plate, short and medium-focal length cameras, the types used for both reconnaissance and mapping, have become more simplified, rugged, and dependable. Although large plate cameras with lenses of 40-inch focal length were developed for high-altitude photography, there is little or no use for such focal lengths in commercial photography. Filters designed to reduce the variation in exposure intensity found in short-focal length wide-angle lenses have been proved comparatively effective. It is possible that tilt may soon be largely eliminated, thus greatly simplifying photogrammetric processes. Further, the development of the package camera (capsule installation) by the Armed Forces means that especially designed photographic aircraft are no longer essential; cameras for any type of photography may be attached to standard aircraft that possess the requisite performance. The increased production facilities and the excess supply in the services, as with aircraft, should utlimately decrease all camera costs.

The excellent resolving power and latitude of negative stocks, the definitive quality as well as density range of positive materials, and the dimensional characteristics of topographic base film and the relatively new waterproof paper leave little to be desired from the geologist's viewpoint. Speeds of aerial films have been increased from 32 to 200 (American Standards Association indices-values approximately half way between Weston and General Electric meter ratings). Although the resolving power of these films is somewhat less, the increased speeds permit satisfactory photography under inferior lighting conditions as well as faster shutter speeds. Reversal films, unfortunately, have not yet equalled the standards of ordinary panchromatic films. Thus, although it is usually considered that at least 10 per cent is lost in each photographic step even under optimum conditions, it is conjectural as to which system yields the better duplicate negative. Infra-red films, while sacrificing speed and shadow detail, have been proved very effective in oblique mapping when preferential scattering of the shortwave lengths has resulted in excessive haze. Although the filter factors of color film in use at present are complicated and the latitude restricted, newer types more nearly approach the characteristics of panchromatic films. These should be of

value in areas where outcropping formations have vivid and characteristic colors. Improvements in color print processes indicate that such techniques may find widespread use in the future. Also, the improvements in printers and dryers have permitted greater production as well as improved quality.

The most important contribution to reconnaissance mapping techniques has been the development of the trimetrogon system by the U. S. Army Air Forces and U. S. Geological Survey.[3] By this method thousands of square miles may be flown in one day by one aircraft for map compilation at scales of 1/100,000 to 1/250,000. Horizon to horizon coverage is obtained by operating three 6-inch metrogon (wide-angle) lens 9×9-inch plate cameras simultaneously with one camera oriented vertically and the two wing cameras with opposing 60° tilt, thus providing about one-inch overlap with the vertical run.

Further, the experience of military photography has shown that such mapping coverage and much of the required interpretative coverage can be obtained on one mission.[4] Since trimetrogon missions are usually flown at altitudes of 20,000 feet, the scale of the verticals is 1/40,000 and the scale of the high obliques varies from approximately 1/40,000 in the overlap area to about 1/80,000 at the centers of the prints (principal points), as much as is ordinarily used. These scales are adequate for reconnaissance evaluation as well as mapping and, since the ground strip covered from oblique center to oblique center is approximately 13 miles wide, it is obvious that such photography is particularly effective. The vertical coverage is also satisfactory for multiplex operations if a more precise mapping project should be undertaken subsequently. Too, the oblique multiplex which was designed for use with oblique trimetrogon photography has considerably greater depth of focus than the vertical multiplex, a fact that may increase the accuracy of trimetrogon mapping as well as permit fairly accurate elevation determinations with ease.

In conjunction with this trimetrogon coverage a camera with a 24-inch focal length, 9×18-inch plate, or 12-inch focal length camera with 9×9-inch plate running simultaneously provides coverage at 1/10,000 or 1/20,000 of a strip 15,000 feet wide, half the width of the vertical 6-inch strip. It was common practice for carrier-based photographic aircraft to carry two simultaneously operating cameras with opposing tilt factors to give a wider strip of coverage for interpretative purposes. While this system is entirely satisfactory for military interpretation, the introduced tilt is confusing when making terrain studies, and it is conjectural if such photography is adequate for geologic interpretation without restitution. It would require two of the previously mentioned cameras with 15° opposing tilt to secure complete coverage of the vertical 6-inch metrogon strip. After the reconnaissance map has been completed and preliminary geologic evaluation effected from the verticals and wing obliques, critical areas that require de-

[3] *Manual of Photogrammetry*, Amer. Soc. Photogrammetry (1944), pp. 645–712.

[4] L. E. Nugent, Jr., "Mapping in the Solomon Islands," *Photog. Eng.*, Vol. 11, No. 2 (1945), pp. 159–69.

tailed interpretation and topographic mapping and that are not included on the large-scale coverage may be easily flown at desired scales with the map as a guide. If photography should no longer be possible, a system of two-stage restitution has been developed which results in considerable enlargement and which has been found satisfactory for the trimetrogon obliques out to the principal points.

A number of more or less minor developments have been made in interpretative instruments. Most mirror-type stereoscopes now have front-surface mirrors, a decided improvement. Although several stereoscopes have been designed especially for viewing color film in rolls or for oblique photographs, it is doubtful that the advantages warrant the cost. A number of sketching devices have been developed, all based on the camera lucida, that permit compilation with ease of tilted photographs or photographs of varying scales. There have also been minor improvements in scales. Substitute devices for height finding have been made that are equally precise but much less than one tenth as expensive as the older types. Simple plotters, sketchers, and templet systems have also been developed that have proven very satisfactory for trimetrogon planimetry.

The Armed Forces found the inclusion of stereopairs the best means of illustration in the various fields of intelligence. As a result, many more stereopairs were used in training manuals, reports, and various studies than had been used by all publications prior to the war. There is little question that the student in general geology, geomorphology, structural geology, and economic geology will also profit from the inclusion of stereopairs in texts and by the supplement of laboratory and field exercises with aerial photographs; because of the area covered obliques should be particularly effective for texts, and stereo-diagrams should facilitate the visualization of three-dimensional structural problems. Although some effort has been made along such lines, to date too few colleges or universities have taken full advantage of the data and techniques offered, particularly in view of the fact that more than two thirds of the United States had been covered photographically by government subsidy prior to the war. Since military experience has shown that less than one person in two hundred is incapable of stereoscopic perception if no unusually organic difficulty exists, and since the acuity of perception increases with practice, it is logical that all geology students should be taught the fundamentals of stereoscopy early. In addition to structural and geomorphic considerations, the correlation of vegetal species, type, and densities with rock derivatives and climatic and altitude/latitude relations should be emphasized as an aid to interpretation. Further, vectograph and twin-stereo projectors have been found effective and may supplement older types to permit three-dimensional classroom presentation. Also, the spatial models presented by vectograph or anaglyph displays lent depth, detail, and perspective impossible with conventional maps or photographs and were advantageous for group military briefing.

It was found, however, that the relatively few stereograms used in texts and periodicals were not entirely satisfactory because of the poor quality of definition

of 133- and 150-line half-tones. Although contact prints give the best definition obtainable in a reproductive and workable medium, such continuous-tone reproduction is prohibitive in cost and undesirable for compilation and binding. While loss of definition and reduction of highlights are inevitable with any half-tone process, in the publication of military interpretative handbooks half-tones produced by 300-line magenta screens and press varnished on a good grade of offset enamel paper were satisfactory for minute detailed interpretation. The use of rose and yellow light also was found excellent in control of negative densities.

Thus, although the role of aerial photography as a valuable and important implement was created by commercial and governmental agencies in the 1930's, the improvements and impetus that resulted from the war will undoubtedly establish photography in its rightful place as an essential adjunct of the geologist in many phases of his work.

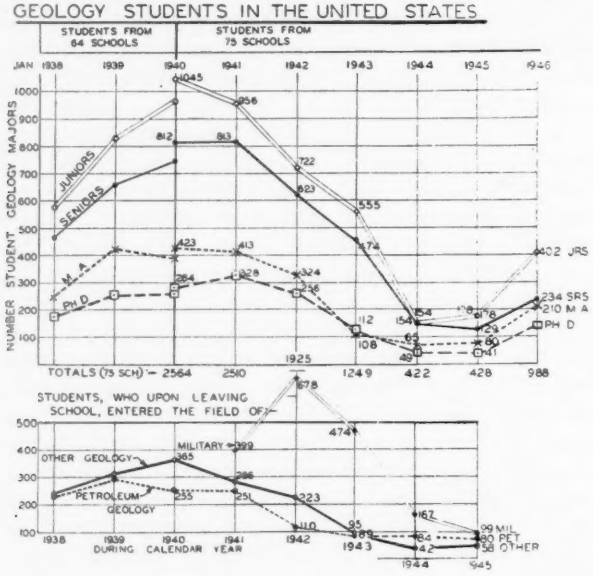
BULLETIN OF THE AMERICAN ASSOCIATION OF PETROLEUM GEOLOGISTS
VOL. 30, NO. 5 (MAY, 1946), P. 730, 1 FIG.

RESEARCH NOTES

SURVEY OF COLLEGE STUDENTS MAJORING IN GEOLOGY

A. I. LEVORSEN
Stanford University, California

The chart is a continuation of the surveys of recent years. It shows the trend in the number of college students majoring in geology in the United States and the placement of those leaving school during the calendar year 1945. The latest figures are for January,



1946. In considering the chart it should be remembered that the figures as of January, 1946, include only the enrollment in the first semester of those colleges using the two-semester system, and the enrollment for the second quarter of those colleges using the quarter system. If a survey were made in April, it would show a further marked increase since it would include the second semester and the spring quarter enrollments.

BULLETIN OF THE AMERICAN ASSOCIATION OF PETROLEUM GEOLOGISTS
VOL. 30, NO. 5 (MAY, 1946), PP. 731-732

REVIEWS AND NEW PUBLICATIONS

* Subjects indicated by asterisk are in the Association library, and are available, for loan, to members and associates.

RECENT PUBLICATIONS

APPALACHIANS

*"Pennsylvanian Geology of a Part of the Southern Appalachian Coal Field," by Harold R. Wanless. *Geol. Soc. America Mem. 13* (New York, January 10, 1946). 162 pp., 40 pls., 1 fig., 9 tables.

ARGENTINA

*"Contribution to Geology of Southwestern Santa Cruz," by José Brandmayr. *Bol. Inform. Petroleras*, Vol. 22, No. 256 (Buenos Aires, December, 1945), pp. 415–43; 6 pls. 1 geologic map in colors, 3 figs. In Spanish.

AUSTRALIA

*"Algal Structures in a Western Australian Salt Lake," by E. deC. Clarke and Curt Teichert. *Amer. Jour. Sci.*, Vol. 244, No. 4 (New Haven, Connecticut, April, 1946), pp. 271–76; 1 fig., 2 pls.

CALIFORNIA

*"Geomorphology of the Middle Kern Basin, Southern Sierra Nevada, California," by Robert W. Webb. *Bull. Geol. Soc. America*, Vol. 57, Nol 4 (New York, April, 1946), pp. 355–82; 7 pls., 5 figs.

COLORADO

*"Operations in World's Highest Field," by Neil Williams. *Oil and Gas Jour.*, Vol. 44, No. 49 (April 13, 1946), pp. 84–87; 5 photographs.

"Stratigraphy of the Golden-Morrison Area, Jefferson County, Colorado," by L. W. Le Roy. *Colorado School of Mines Quar.*, Vol. 41, No. 2 (Golden, April, 1946). 160 pp., 23 figs., 11 pls., detailed sections, bibliography. Price, $1.50.

FLORIDA

*"North Florida Province Is Geologically Attractive," By John D. Todd. *World Petroleum*, Vol. 17, No. 3 (New York, March, 1946), pp. 44–46, 94; 2 pls.

GENERAL

*"The Fluorgraphic Method of Petroleum Exploration," by Orton E. Campbell. *World Petroleum*, Vol. 17, No. 3 (New York, March, 1946), pp. 54–56; 4 maps. 3 fluorlogs.

*"Aerial Photography Aids Geologist," by Frank A. Melton. *Oil Weekly*, Vol. 121, No. 4 (Houston, March 25, 1946), pp. 48, 50, 65; 2 figs.

**Petroleum Register*, 24th annual edition, 1945–1946. National oil directory. Foreign section, featuring South America. 600 pp. Published in Los Angeles and New York. Southwestern representative, Dudley W. Moore, Box 1826, Tulsa, Oklahoma. Price, $10, postpaid in U. S.; $12, postpaid to other parts of the world.

The Wildcatters, by Samuel W. Tait, Jr. An informal history of oil-hunting in America. 230 pp., 23 photographs. Princeton University Press, Princeton, New Jersey. Price, $3.00.

*"Geotechniques of Oil Exploration," by John W. Merritt. *Oil Weekly*, Vol. 121, No. 5 (Houston, April 1, 1946), pp. 17–22, 26; 6 figs.

*"An Integration of Coral-Reef Hypotheses," by Harold T. Stearns. *Amer. Jour. Sci.*, Vol. 244, No. 4 (New Haven, Connecticut, April, 1946), pp. 245–62; 6 figs.

*"'High Potential' Areas in North America," by Ronald L. Ives. *Ibid.*, pp. 263–70; 3 figs.

**Bibliography and Index of Geology Exclusive of North America*, by John M. Nickles, Marie Siegrist, and Eleanor Tatge. Vol. 10, 1943–1944 (1946). 203 pp. Published by Geological Society of America, 419 West 117th Street, New York 27, N. Y.

*"Ordovician Cephalopods of the Cincinnati Region," Pt. 1, by Rousseau H. Flower. *Bulletins of Amer. Paleontology*, Vol. 29, No. 116 (March 21, 1946). 751 pp., 50 pls., 21 figs.

NEW MEXICO

"Lucero Uplift, Valencia, Socorro, and Bernallilo Counties, New Mexico," by V. C. Kelly and G. H. Wood, Jr., *U. S. Geol. Survey Prelim. Map. 47* (March, 1946). Sheet, 44×56 inches. Scale, 1 inch equals 1 mile. Geological Survey, Washington 25, D. C.; Denver, Colorado; Tulsa, Oklahoma.

OHIO, PENNSYLVANIA, WEST VIRGINIA

"Map of Berea and Murrysville Sands of Northeastern Ohio, Western Pennsylvania and Northermost West Virginia," by Davis F. Demarest. *U. S. Geol. Survey Prelim. Map 49*, Oil and Gas Investig. Ser. (March, 1946). Sheet, 40×60 inches. Scale, 1 inch equals 3 miles. May be purchased from Director, Geological Survey, Washington 25, D. C. Price, $0.60.

"The Stratigraphic Relationship of the Berea, Corry, and Cussewago Sandstones in Northeastern Ohio and Northwestern Pennsylvania," by Wallace DeWitt, Jr. *Ibid., Prelim. Chart 21* (April, 1946). Price, $0.40.

PACIFIC COAST

*"'Progress in Paleontological Research on the Pacific Coast; 1917–1944," by Chester Stock. *Bull. Geol. Soc. America*, Vol. 57, No. 4 (New York, April, 1946), pp. 319–54.

PENNSYLVANIA

"Oil and Gas Field Property Line Maps of the Hilliards Quadrangle, Pennsylvania," by R. E. Sherrill. *Pennsylvania Topog. and Geol. Survey Spec. Bull. 3* (1946). Nine maps on scale of 1 inch equals 2,000 feet. Division of Documents, Dept. of Property and Supplies, 10th and Market Streets, Harrisburg. Price, $1.00.

UTAH

*Areal Geologic Map of the Green River Desert-Cararact Region, Emery, Wayne, and Garfield Counties, Utah," by A. A. Baker. *U. S. Geol. Survey Prelim. Map 55*, Oil and Gas Investig. Ser. (April, 1946). Sheet, 28×45 inches. Scale, 1 inch equals 2 miles. Geological Survey, Washington 25, D. C.; Denver, Colorado; Tulsa, Oklahoma. Price, $0.40.

WYOMING

"Geologic and Structure-Contour Map of Sage Creek Dome, Fremont County, Wyoming," by H. H. R. Sharkey, Alfred Zapp, C. O. Johnson, *et al. U. S. Geol. Survey Prelim. Map 53*, Oil and Gas Investig. Ser. (April, 1946). Single sheet, 34×47 inches. Scale, 2 inches equal 1 mile. Geological Survey, Washington 25, D. C.; Casper, Wyoming; Denver, Colorado; Tulsa, Oklahoma. Price, $0.50.

"Engineering Report on the Water Problem in the Embar Formation of the South Oregon Basin Field, Wyoming," *U. S. Geol. Survey* (April, 1946). 14 pp., 21 maps, sections, plates, tables. Available for public inspection in the open files of the Geological Survey offices in Thermopolis, Wyoming; Casper, Wyoming; and in the Geological Survey Library, Room 1033, Federal Works Agency Building, Washington, D. C.

BULLETIN OF THE AMERICAN ASSOCIATION OF PETROLEUM GEOLOGISTS
VOL. 30, NO. 5 (MAY, 1946), PP. 733-801, 11 FIGS.

THE ASSOCIATION ROUND TABLE

WILLIAM HARVEY EMMONS—HONORARY MEMBER

A. I. LEVORSEN
Stanford University, California

William Harvey Emmons, who has been elected an honorary member of the Association, was born in Mexico, Missouri, on February 1, 1876. After securing his A.B. degree at Central College, Missouri, in 1897 he went to the University of Chicago as a Fellow and there obtained his Ph.D. degree in 1904. For the next few years he continued on at



FIG. 1.—Honorary member EMMONS receiving president CHENEY's congratulations. Thirty-first annual meeting of the Association, Chicago, April 3, 1946.

Chicago as lecturer, assistant professor, and associate professor of economic geology and as an aid on the United States Geological Survey. In 1911 he was called to the University of Minnesota to become head of its Geology Department, and at the same time became director of the Minnesota Geological Survey. He held these two positions until his retirement in June, 1944.

He was a geologist on the United States Geological Survey from 1909 to 1915 and during this period published a number of bulletins and professional papers on various ore

deposits of the United States. During this period his chief interest was in the superficial alteration and secondary enrichment of copper deposits, and later in the development of the theory of the zonal arrangement of lode deposits throughout the world. His *Bulletin 625* of the Geological Survey on the principles of secondary enrichment of ore bodies was published in 1917 and is still the classic treatise on the subject.

Along with the interest he had in ores and economic geology, he developed a strong interest in the field of petroleum geology and published his textbook, *The Geology of Petroleum*, in 1921, followed by a second edition in 1931. This book, which was one of the first on the subject, brought together lectures he had been giving on petroleum geology at the universities of Chicago and Minnesota. Its great influence in the field of petroleum geology is evidenced by its wide use as a college textbook for the past 25 years throughout the world and its translation into eleven foreign languages. As a consequence he is probably as well known outside the United States for petroleum geology as any other geologist. In addition to books on economic geology and petroleum geology, he has written *Gold Deposits of the World*, and has collaborated on a textbook on *General Geology*. These books, in addition to the many articles and other scientific writings, furnish a powerful testimony to his geologic productivity.

He has been a member of our Association since 1919. In 1921 he was a member of a mining commission which went to China to advise on its mineral resources; has examined mining properties in many parts of the world; and has acted as consultant to many mining and oil operators. He was president of the Society of Economic Geologists in 1928 and in 1942 was recipient of its Penrose Medal.

Professor Emmons has always been a prodigious worker and has produced a large number of contributions to the science of economic geology. He has often emphasized the close relationship between the geology of the ores and of petroleum, both being fundamentally the relations of liquids and gases in permeable rocks under varying conditions of temperature and pressure. His ideas of the zonal arrangement of ore deposits on the periphery of batholiths was inspired by his understanding of the geology of petroleum and its accumulation in structurally high parts of the reservoir rocks.

One of his outstanding characteristics is the intense enthusiasm with which he approaches all things geological in which he is interested. His great success as a teacher is in a large measure due to his ability to transfer this enthusiasm to his students, of which there are more than 600 who have become professional geologists, many in the field of petroleum. While attending the University of Minnesota it was my good fortune to be employed by him as a draftsman on his first book on economic geology and I can well attest this enthusiasm for geology. Many a night was spent drawing diagrams and maps until one or two o'clock in the morning under his close supervision and then we both had eight o'clock classes to make! Such a schedule was a common occurrence and during those periods when he was under the stimulation of working with new ideas, the concentration he was able to bring to bear on his problems was phenomenal.

Professor Emmons combines an unusually friendly and jovial disposition with his ability as a research worker—a rare combination indeed! His chief interest and thought have always been for the welfare of his students and a sincere desire to aid them in a successful career in geology. The warm personal ties he has developed with many mineral-industry operators have done much to arouse their interest in geology and his knowledge of the practical conditions in the mineral industry has been of great benefit in guiding students into fields that are both interesting and remunerative. His host of friends rejoice with him for this new honor that has come to him!

ELIAS HOWARD SELLARDS—HONORARY MEMBER

M. G. CHENEY
Coleman, Texas

The varied rocks, fossils, mineral resources, and physiographic features of his native Kentucky evidently presented a challenge to Elias Howard Sellards during his formative years. University training in these and related subjects brought him A.B. and A.M. degrees at the University of Kansas in 1899 and 1900. His work as field assistant of Carnegie Museum and further graduate studies earned the degree of Doctor of Philosophy



FIG. 1.—Honorary member SELLARDS receiving president CHENEY's congratulations. Thirty-first annual meeting of the Association, Chicago, April 3, 1946.

from Yale University in 1903. After one year's teaching at Rutgers University he became professor of geology and zoology at the University of Florida; then, State geologist of Florida from 1907 to 1918. During this period his work on fossil man, underground waters, and phosphates brought him into prominence.

Rapidly increasing importance of petroleum developments in Texas attracted his interest and attention. From 1918 he served the Bureau of Geology of the University of Texas as geologist to 1925, then associate director from 1925 to 1932 and finally as director from 1932 to 1945. Other duties at the University of Texas brought him the title of professor of geology in 1926 and director of the Texas Memorial Museum since 1938. Under his guidance a very instructive display of vertebrate and invertebrate fossils has

been assembled and beautifully arranged, along with many models of the historical and present geologic and physiographic features of Texas.

Professor Sellards has rendered very important service to the science of petroleum geology through his many geological treatises and maps as well as helpful cooperation with geological societies. His map and article in 1918 on the underground position of the Ellenburger rocks in north-central Texas definitely established the presence of a major structural feature, generally referred to as the Bend arch, in that region. His works of greatest help to petroleum geologists include comprehensive volumes in 1932 and 1934 on the stratigraphy and geologic structure of Texas, his own writing dealing chiefly with Paleozoic rocks and structural features east of the Pecos River. The structural map of the entire state of Texas first published in 1936, showing location of oil and gas fields, has been of great service. The more recent map on mineral localities in Texas will no doubt be widely used.

Extensive service to the geological profession was also rendered by Professor Sellards through the years as a member (1931–1934) of the Division of Geology and Geography, National Research Council; councilor (1938–1940) and vice-president (1943) of the Geological Society of America; president (1938) of the Society of Economic Paleontologists and Mineralogists; and president (1942) of the Paleontological Society. He has also been an active member of the Society of Vertebrate Paleontologists and the Society of Economic Geologists, and since 1919 the American Association of Petroleum Geologists.

Because of these many contributions to the cause of petroleum geology and to geology in general, the executive committee elected Elias Howard Sellards an honorary member of the Association, February 28, 1946.

HORACE GARDINER RICHARDS—RECIPIENT OF PRESIDENT'S AWARD

FRANK R. CLARK[1]
Tulsa, Oklahoma

The President's Award for 1945 was presented with appropriate ceremony on April 3, 1946, during the annual meeting at Chicago, Illinois, to Horace Gardiner Richards for his article, "Subsurface Stratigraphy of Atlantic Coastal Plain between New Jersey and Georgia," published in the July, 1945, *Bulletin* of the Association.

This is the second presentation of this award which consists of $100 cash plus a citation. To be eligible for the award an author must not have passed his fortieth birthday on the first day of the year in which his article is published. The selection of the candidate is the function of the medal award committee under the established rules and upon approval by the executive committee, the candidate is declared the recipient of the award.

Richards is a native of Pennsylvania, having been born in Philadelphia, March 21, 1906. He is the son of the late Horace G. Richards, professor of physics at the University of Pennsylvania, and Annie G. Richards.

He was educated at the Penn Charter School in Philadelphia and at the University of Pennsylvania where he received his A.B. and M.S. degrees in 1927 and 1929, respectively.

He received the Harrison Fellowship and obtained the Doctor's degree in 1932 with a thesis on "Marine Fossils from New Jersey Indicating a Mild Interglacial Stage."

He was associated with the United States Bureau of Fisheries and collected and studied the marine life from the shores of New Jersey. He was at the United States National Museum in 1931 and 1932.

He became research associate at the New Jersey State Museum in Trenton, New

[1] Chairman, medal award committee.

Jersey, in 1934, working on local geological problems together with educational and curatorial duties.

In 1938 he became research associate at the Academy of Natural Sciences of Philadelphia, and in 1942 was appointed associate curator of geology and paleontology, a position which he still holds.



HORACE GARDINER RICHARDS

To further his geological research, he received several grants from the Geological Society of America, the American Philosophical Society, and the Carnegie Institution of Washington. These enabled him to broaden his fields and to do geological work in Mexico, Central America, the Islands of the Caribbean, and in Canada as far north as Hudson Bay.

He has specialized in lectures on his work, both of a popular and scientific nature, and

is particularly interested in photography as a means of illustrating geological localities.

In addition to his membership in the A.A.P.G., Richards is a member of the following scientific organizations.

American Association for the Advance of Science
American Soviet Science Society
American Malacological Union
Geological Society of America
Paleontological Society
Pennsylvania Academy of Science
Sigma Xi

In addition to the article for which he was given the award, Richards is the author of seventy-four titles, the most important of which follow.

* Marine Fossils from New Jersey Indicating a Mild Interglacial Stage, *Proc. Amer. Philos. Soc.*, Vol. 82, pp. 181–214 (1933)

* Correlation of Late Pleistocene Marine and Glacial Deposits of New Jersey and New York (with Paul MacClintock), *Bull. Geol. Soc. America*, Vol. 47, pp. 289–338 (1936)

* Fauna of the Pleistocene Pamlico Formation of the Southern Atlantic Coastal Plain, *Bull. Geol. Soc. America*, Vol. 47, pp. 611–1656 (1936)

Land and Freshwater Mollusks from the Island of Cozumel, Mexico and Their Bearing on the Geological History of the Region, *Proc. Amer. Philos. Soc.*, Vol. 77, pp. 249–262 (1937)

* Marine Pleistocene Mollusks as Indicators of Time and Ecological Conditions, in book *Early Man*, pp. 75–84. J. B. Lippincott, Philadelphia (1937)

Land Mollusks from the Island of Roatao, Honduras, *Proc. Amer. Philos. Soc.*, Vol. 79, pp. 167–78 (1938)

* Marine Pleistocene of Florida, *Bull. Geol. Soc. America*, Vol. 49, pp. 1267–96 (1938)

* Marine Pleistocene of the Gulf Coastal Plain: Alabama, Mississippi and Louisiana, *Bull. Geol. Soc. America*, Vol. 50, pp. 297–316 (1939)

Land Mollusks from Corn Island, Nicaragua, *Proc. Amer. Philos. Soc.*, Vol. 81, pp. 29–36 (1939)

* Marine Pleistocene of Texas, *Bull. Geol. Soc. America*, Vol. 50, pp. 1885–98 (1939)

* Miocene Invertebrate Fauna of New Jersey (with Anne Harbison), *Proc. Acad. Nat. Sci. Philadelphia*, Vol. 94, pp. 167–250, Pls. 7–22 (1942)

* Pliocene and Pleistocene Mollusks from the Santee-Cooper Canal Area, South Carolina, *Acad. Nat. Sci. Philadelphia Notulae Naturae No. 118* (1943)

* Studies on the Geology and Paleontology of the North Carolina Coastal Plain, *Amer. Philos. Soc. Yearbook for 1942*, pp. 110–19 (1943)

* Fauna of the Raritan Formation of New Jersey, *Proc. Acad. Nat. Sci. Philadelphia*, Vol. 94, pp. 15–32, Pls. 4–7 (1943)

* Additions to the Fauna of the Trent Marl of North Carolina, *Jour. Paleon.*, Vol. 17, pp. 518–26, Pls. 84–6 (1943)

* Correlation of Atlantic Coastal Plain Cenozoic Formations: a Discussion, *Bull. Geol. Soc. America*, Vol. 56, pp. 401–08 (1945)

* Deep Oil Test at Salisbury, Wicomico County, Maryland, *Bull. Amer. Assoc. Petrol. Geol.*, Vol. 29, pp. 1196–1202 (1945)

Animals of the Seashore. Bruce Humphries, Boston (1938)

THIRTY-FIRST ANNUAL MEETING
STEVENS HOTEL, CHICAGO, ILLINOIS

APRIL 1–4, 1946

The annual meeting in Chicago—the second time in the 31 years of A.A.P.G. meetings—served well the high purposes of the Association. The program included an acceptable selection of subjects—geological, paleontological, petrologic, and geophysical—and the hotel and the city possessed ample temptations for various diversion.

The attendance of 1,300, more or less, total members and friends, is comparable with the number in Chicago six years ago. It is interesting to note that the A.A.P.G. convention attendance curve does not parallel the growth in membership. Since 1940, the at-

* Subjects on East Coast geology

tendance maximum was set at 2,800 at Houston in 1941, and the minimum was at Tulsa in 1945 because of war-time restrictions to less than 50 persons outside of local residents. During the period of the war years, the number of members increased more rapidly than ever before—from 3,240 to 4,670—in spite of, or probably because of, the war. For the first meeting held amid the uncertainties and hazards of World Peace II, the Chicago attendance this year was indicative of larger meetings to come.

The registration counter was open for business on Sunday, March 31, staffed by four girls from the Tulsa headquarters office and four from the Chicago Convention Bureau. Conveniently placed on the second floor, facing the elevators, it was, as usual, the starting and departing point. The technical sessions were comfortably accommodated in the Grand Ball Room on the second floor, and in more crowded assembly rooms on the third floor. A dozen committee groups, large and small, met on the third and fourth floors and in the private rooms of officers and chairmen. In general, acoustics were good and the sound amplifiers adequate. The projection of illustrations on the screen we never expect to see in perfect presentation at an A.A.P.G. meeting; individual authors continue to overcrowd their slides with detail. In large rooms only few and simple data can be clearly presented; details should be left for printed publication.

Oil-field and laboratory exhibits were missing this year and the advertising pages in the printed program seemed to draw attention to the absence of these displays of other years which many members have come to think of as essential to the success of the convention.

The application of the earth sciences to military activity received prominent place in the program. Several papers dealt with the first-hand observation and experience of geologists and geophysicists in the war. Otherwise, the conferences and sessions concentrated on topics of long standing that have made the geologist what he is and will continue to demand his attention and services as the earth continues to hide its secrets—research in general and in particular, tectonics, oil-field problems, trends and developments, sedimentation, and the Permian!

Special events relieved the continuity of the technical papers. Honorary membership certificates were presented to William Harvey Emmons, of the University of Minnesota, and to Elias Howard Sellards, of the University of Texas. The one-hundred-dollar President's award went to Horace Gardiner Richards, of the Academy of Natural Sciences, Philadelphia.

On Tuesday night, Eugene Holman, president of the Standard Oil Company (New Jersey), addressed his fellow members. His subject was "Facing Forward." We like to think that he exemplified the fulfillment of the aspirations of some young geologist in that audience.

On Wednesday night, 725 attended the dinner-dance in the Grand Ball Room. Beautiful red roses, a 12-piece orchestra, and a first-rate floor show added to the warmth and vivacity of the occasion.

On Thursday afternoon, the Association convened in annual business meeting and listened to the reports of officers and the recommendations of the business committee. Lack of full attendance did not dampen debate on two important matters. The decision about simplifying the code of ethics and about adopting a mailed ballot system for electing officers was referred to the vote of the members by mail.

On Friday morning, the Illinois Geological Society sponsored a field trip of 17 participants to see Devonian-Silurian sections in cuts and quarries in the Chicago-Joliet area.

The imprint of war still marked this first meeting since the fighting officially ceased. The Association Service flag hung from the balcony back of the speaker's desk. A memorial service at the beginning of the meeting drew attention to the fact that more than 700 of our members had entered the Armed Forces, and 14 would not come back. On the

Saturday following the meeting, mile upon mile of marching soldiers and rumbling tanks in celebration of Army Day gave impressive evidence that the world is not yet wholly at peace.

For another year we take with us, from the cover pages of the convention program, the thoughts, "Oil Must Be Discovered," "More Exploration Is Needed," and the realization that the publications of our three societies form the authoritative record of scientific petroleum exploration.

Program of Technical Papers

Tuesday Morning, April 2

Grand Ball Room, Stevens Hotel

Joint Session of A.A.P.G., S.E.P.M., and S.E.G.
Presidential and Special Addresses

10:00 A.M.—12:00 Noon

Monroe G. Cheney and Morris M. Leighton, *Presiding*

1. 10:00 Theron Wasson, Chief Geologist, The Pure Oil Company, Chicago.
   Address of Welcome.
2. 10:05 Announcements.
3. 10:10 Memorial Service. A. Rodger Denison, Leader.
4. 10:15 Henry C. Cortes, Magnolia Petroleum Company, Dallas, Texas.
   S.E.G. *Presidential Address:* Geophysical Case History. Vol. 1.
5. 10:45 John R. Sandidge, Magnolia Petroleum Company, San Antonio, Texas.
   S. E. P. M. *Presidential Address: Expanding Activities of Paleontologists.*
6. 11:10 Monroe G. Cheney, Anzac Oil Corporation, Coleman, Texas.
   A.A.P.G. *Presidential Address: The Geological Attack.*
7. 11:30 Carey Croneis, President, Beloit College, Beloit, Wisconsin.
   Geology and Science Legislation.

   This paper is concerned with (1) present status of Geology as a collegiate and post-graduate discipline, as a science, and as a profession, and (2) the possible future status of Geology, in all its ramifications, should there be established through legislative action one of the several types of National Science Foundations which have been proposed.

Tuesday Afternoon, April 2

Grand Ball Room

Application of Geology to Military Science
and Special Papers

2:00 p.m.—5:00 p.m.

Fritz L. Aurin and Earl B. Noble, *Presiding*

1. 2:00 W. P. T. Hill, Major General, United States Marine Corps, Washington, D. C.
   The Application of Geology to Military Activities.

   Science of land forms and topographic features. Natural features. Erosional and depositional processes. Surface expression. Physiographic interpretation. Offshore, beach, and immediate hinterland features. Geologic, topographic soil features and vegetation as barriers to Military operations As applicable to beach or amphibious operations. The particular adaptability of the geologist as an interpreter of aerial photograph's use in the study of landing beaches et cetera. Examples of some geological problems in Amphibious operations in the Pacific. Examples of geological problems after landings in Amphibious operations in the Pacific. Water Supply. Materials for construction of air fields, roads, et cetera.

2. 2:15 Paul H. Price, State Geologist, West Virginia Geological and Economic Survey, Morgantown, West Virginia.
   Geologists in Service (European Theater).

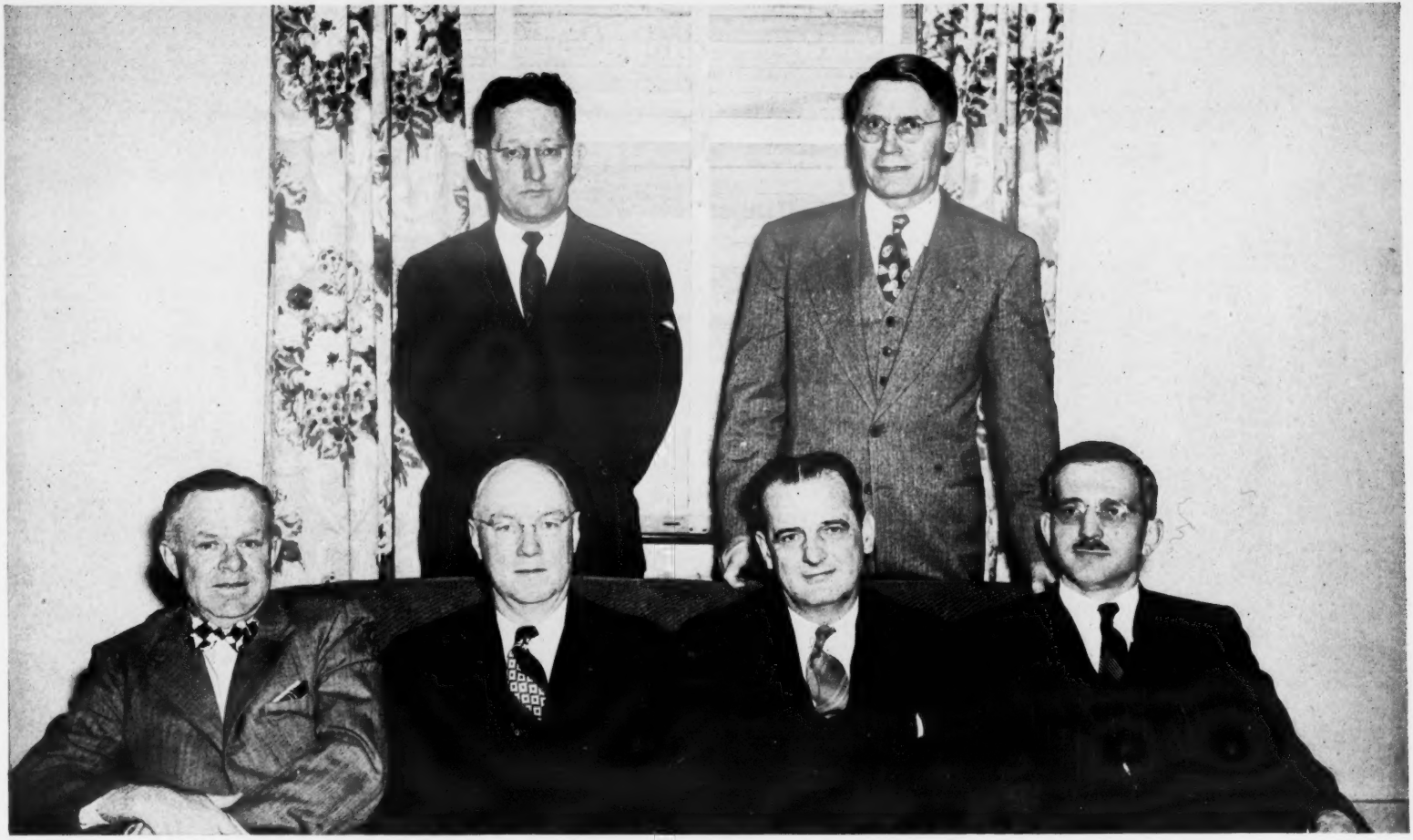
   Geologists were used in this war, both in uniform and as civilians, more than during World War I.

   World War III will perhaps show little similarity to those of the past and the question arises as to the value of geology and the geologist in a war of robot planes, atomic bombs, and similar scientific developments.



Curtis Biltmore Studios, Los Angeles

1.—Earl B. Noble, president of the Association.

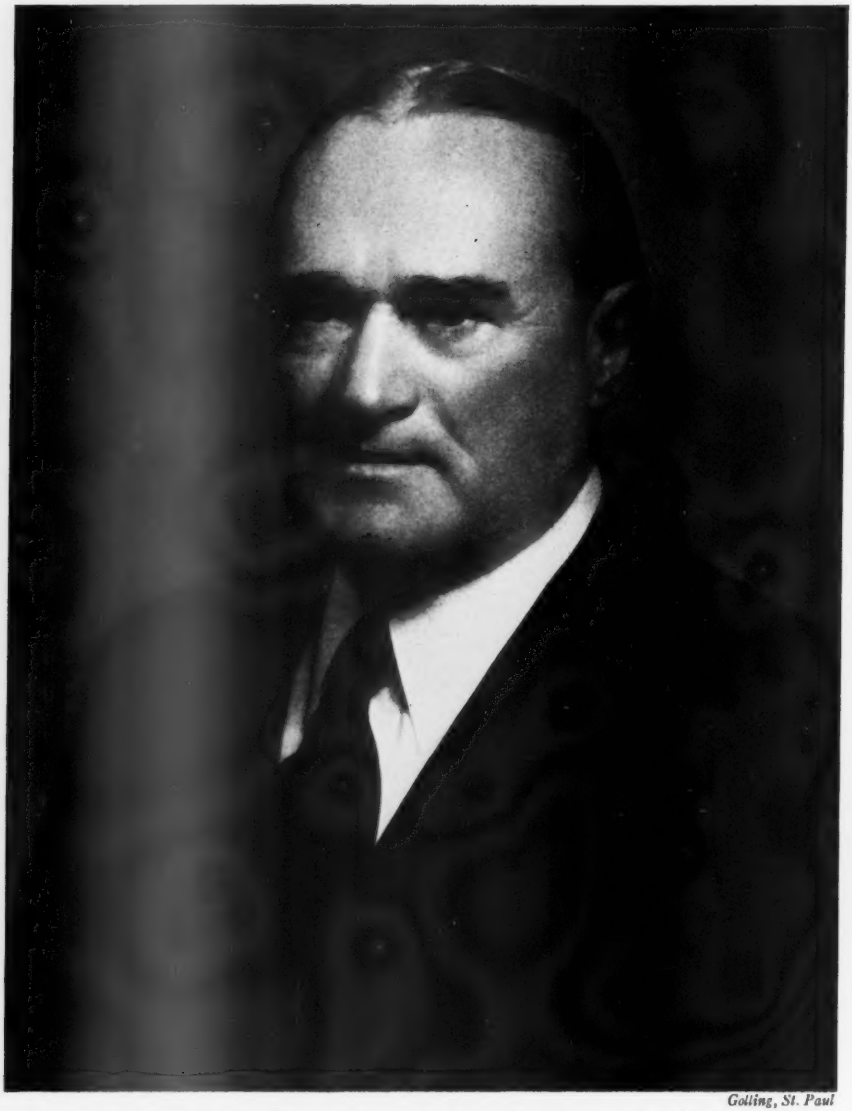


2.—Executive committee. Incoming, seated, left to right: GAYLE SCOTT, editor (re-elected); EARL B. NOBLE, president; D. PERRY OLCOTT, vice-president; EDWARD A. KOESTER, secretary-treasurer (re-elected). Outgoing, standing, left to right: IRA H. CRAM, past-president; M.G. CHENEY, president; absent, vice-president M. GORDON GULLEY. Thirty-first annual meeting of the Association, Chicago, April 4, 1946.

ing of the Association, Chicago, April 4, 1946.



3.—Honorary members ELIAS H. SELLARDS and WILLIAM H. EMMONS (left and right). HORACE G. RICHARDS (center), recipient of the President's award. Thirty-first annual meeting of the Association, Chicago, April 3, 1946.

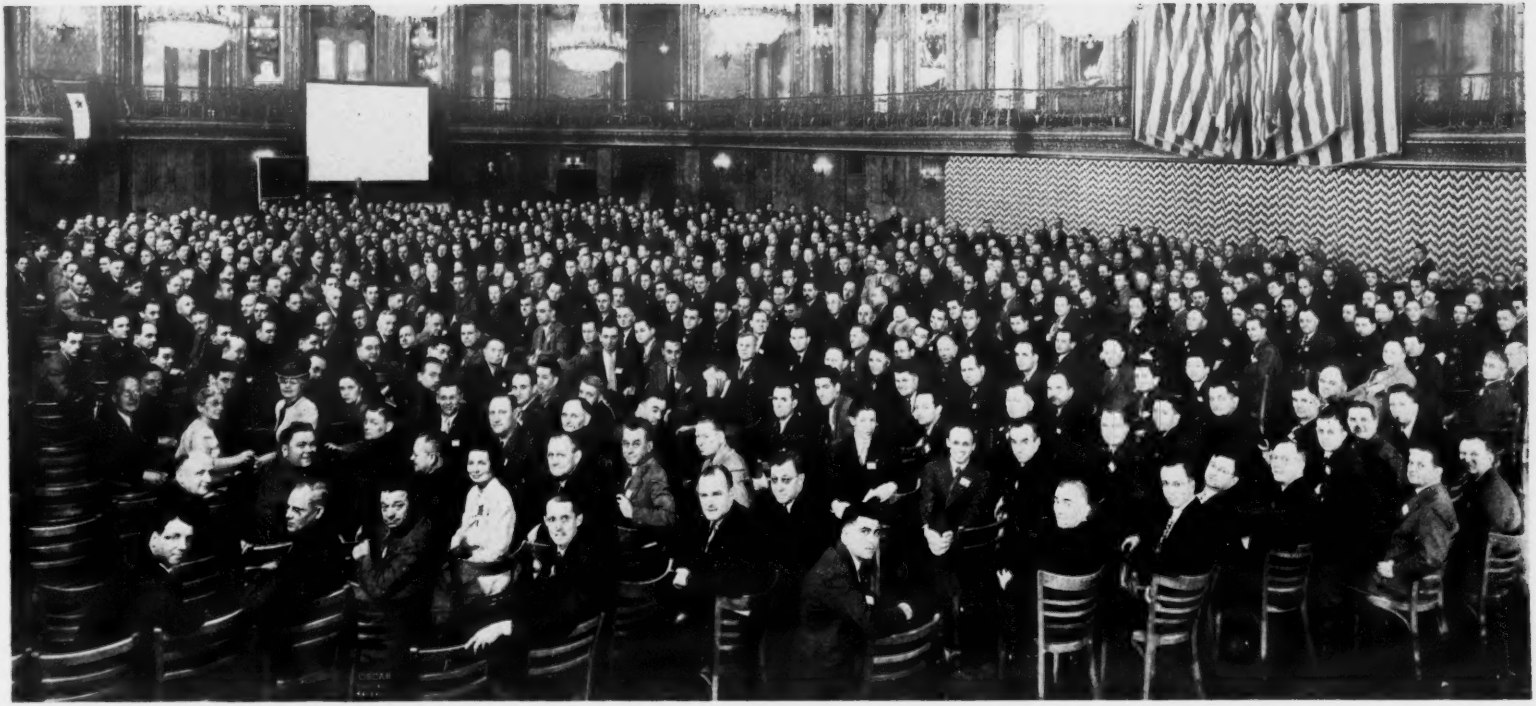


Golling, St. Paul

4.—William Harvey Emmons, honorary member of the American Association of Petroleum Geologists, elected February 28, 1946.



5.—ELIAS HOWARD SELLARDS, honorary member of the American Association of Petroleum Geologists, elected February 28, 1946. Sketch portrait by Raymond C. Moore, republished from *Journal* of the Association of American State Geologists.



6.—Joint annual meeting of A.A.P.G., S.E.P.M., and S.E.G., Grand Ball Room, Stevens Hotel, Chicago, April 2, 1946.
M. M. LEIGHTON presiding; president M. G. CHENEY at the speaker's desk.



7.—Dinner-dance, Grand Ball Room, Stevens Hotel, Chicago, April 3, 1946. Thirty-first annual meeting of the Association.



8.—Dinner-dance, Grand Ball Room, Stevens Hotel, Chicago, April 3, 1946. Thirty-first annual meeting of the Association.

Geologists are of greatest value for war during times of peace by assembling and coordinating complete data concerning all parts of the earth.

3. 2:40 WILLIAM C. PUTNAM, Associate Professor of Geology, University of California, Los Angeles, California.
The Use of Geology in the Southwest Pacific Area.

The Southwest Pacific theater apparently was unique in first utilizing geologists to some degree as geologists and not as photo-interpreters, pilots, infantrymen, or in other military capacities bearing little or no relation to their specialized training. Four geologists, Lincoln Dryden (Beach Erosion Board), James Gilluly, A. Nelson Sayre, and the author (Military Geology Unit, U. S. Geological Survey), were assigned to the Office of the Chief Engineer, General Headquarters, and one or another participated in the Morotai, Leyte, and Luzon operations. The work consisted in making terrane and beach studies, developing water supplies, selecting airfield sites, and locating engineer resources.

The practical application of geology to military and engineering problems was appreciated by a few individuals, but not by the Army as a whole. Many examples occurred where obvious applications of geology were ignored, with delay and inefficiency as the result. The organization of the Army appears to prevent efficient use of specialized training. It is apparent from this war that no army can expect to win a future conflict that does not exploit science and technology to their utmost. If geologists are to fulfill their obligation to society, it is their duty to see that the Army, as well as the public, is made aware of what geology is, and what contributions it reasonably can be expected to make.

4. 3:10 EDGAR W. OWEN, Geologist, c/o L. H. Wentz, San Antonio, Texas.
Aptitude of Geologists in War Effort.

5. 3:30 CHARLES B. HUNT, United States Geological Survey, Salt Lake City, Utah. (Published by permission of the director of the United States Geological Survey.)
Geology's Place in the Military Organization.

6. 3:45 FRED B. PHLEGER, JR., Woods Hole Oceanographic Institution, Woods Hole, Massachusetts.
Oceanography and Petroleum Geology.

In the last few years oceanography has become a distinctive and relatively mature science, due to the development of new oceanographic techniques and the training of personnel. The problems of petroleum geology which can be attacked by oceanographic research are, principally: (1) the methods of accumulation and recognition of the source sediments of petroleum, and (2) the environment of accumulation and the interpretation of reservoir rocks and associated marine sediments. These problems require extensive and detailed description and interpretation of the environments under which different marine sediments are at present accumulating. All studies of Recent marine sediments and their organic remains should be related to the physical, chemical, and biological nature of the entire water mass, and should not be studied as a separate problem. Studies in offshore and deep-water areas may be as important as in nearshore and shallow-water areas.

Investigation of Recent possible source sediments of petroleum should include the distribution of the organisms which constitute the source of supply, the distribution of these organic materials after they are incorporated into the sediments, and the processes involved in the preservation and accumulation of the materials in the sediments. The sediments themselves can be studied by systematic collection of surface samples and short cores, and analyzed for grain size distribution, mineralogy, water content, and mass physical properties. The ecology of organisms useful as fossils, particularly Foraminifera, should be studied in some detail. Both pelagic and benthonic living populations must be analyzed quantitatively, and these should be related to the accumulation of the skeletons in the sediments.

Modern oceanographic techniques are readily adaptable to working on these problems, and considerable research either is underway or is planned for the future. There is little real knowledge of these problems in sedimentation and related features of the marine environments. It is believed that an increased tempo of research in pertinent phases of oceanography would assist in clarifying many of the basic problems of petroleum geology.

7. 4:10 W. C. SCHROEDER, Chief, Office of Synthetic Liquid Fuels, United States Bureau of Mines, Washington, D. C.
Synthetic Oil and Gasoline Industry of Germany.

In the early part of 1945, as advancing allied armies began to overrun Germany, a group of industrial and governmental specialists was organized to examine the synthetic fuel plants as rapidly as they were captured. Germany had built up a large industry for the production of aviation gasoline, Diesel fuel, lubricating oil and a large variety of chemical products from coal by means of the hydrogenation and Fischer-Tropsch processes. During the course of the war these processes provided $\frac{1}{3}$

to ⅔ of their total gasoline and oil. The industry was based on a research and engineering effort dating from 1913 in a field in which there was little knowledge in the United States.

More than 30 investigators devoted 4 to 8 months to the work. They examined bombed plants, interrogated German scientists and engineers, and evacuated all reports, documents, and drawings necessary to furnish information on the plants and processes. These data have now been brought to the United States, and about 16 groups of technologists are working to translate, correlate, and prepare the material for general dissemination. The results are particularly useful to the Bureau of Mines in the present synthetic fuel program under the Synthetic Liquid Fuel Act passed in 1944, as well as useful to the oil and coal industries with respect to the production of liquid fuels and lubricants. Special attention is given to those phases of the German processes which may be used in the United States.

8. 4:35 D. PERRY OLCOTT, Humble Oil and Refining Company, Houston, Texas.
History of the Reserves and Production of Natural Gas and Natural Gas Liquids in Texas.

The natural gas and natural gas liquids reserves have been divided into three categories because of current producing and regulatory practices. These categories are (1) non-associated gas (free), (2) associated gas (gas cap), and (3) dissolved gas. The total reserves of these three categories in Texas as of January 1, 1946, were about 75 trillion cubic feet, divided (1) 67 per cent, (2) 23 per cent, and (3) 7 per cent. The number and volume of natural gas discoveries have increased materially in recent years, and the year-end reserve has increased steadily.

Natural gas liquids are defined as the liquids being recovered from the three categories of gas by current plant or field practices. The total natural gas liquids reserves in Texas were about 1.4 billion barrels with about 50 per cent in the non-associated gas, 15 per cent in the associated gas, and 35 per cent in the dissolved gas.

The gauged gas production in Texas in 1945 was about 2.6 trillion cubic feet or a daily average of 71 billion cubic feet. The natural gas liquids produced during 1945 in Texas amounted to about 59 million barrels or a daily average of 162,000 barrels.

WEDNESDAY MORNING, APRIL 3

Grand Ball Room

TECTONICS

9:00 a.m.—12:00 Noon

PHILIP B. KING AND C. W. TOMLINSON, *Presiding*

1. 9:00 CHESTER R. LONGWELL, Professor of Geology, Yale University, New Haven, Connecticut.
Tectonic Maps and Tectonic Provinces of the United States.

Various devices have been used on maps, by European and American geologists, for portraying geologic structure. Some ordinary geologic maps serve the purpose reasonably well. Other maps omit representation of bedrock units and employ distinctive symbols for structural feaures only. Most "tectonic" maps combine, in varying proportions, lithologic structural conventions.

The Committee on Tectonics of the National Research Council, in laying plans for improving the tectonic map of the United States, is considering the following suggestions: (1) correction of errors, and addition of new information as it becomes available; (2) extension of the map into Canada and Mexico as far as reliable information will permit; (3) representation, perhaps in part on auxiliary maps, of superposed structural patterns separated by unconformities; (4) development of symbols and color schemes that may make the map more effective as a wall map, by bringing out major tectonic units more clearly; (5) possible delineation of "tectonic provinces." Differences of opinion will develop in attempting a practical definition of a "tectonic province." Is type of structure, or geologic date of development, the more essential criterion; or must both of these elements be considered? Several provinces are fairly distinctive, on either basis; others are more or less confused. Some tentative and questionable boundaries will be necessary in any representation of the concept on a map.

No map can be fully self-explanatory. A treatise to supplement and interpret the tectonic map is a worthy project.

2. 9:30 W. T. THOM, JR., Professor of Geology, Princeton University, Princeton, New Jersey.
Post-Triassic Evolution of a Part of the Atlantic Coastal Region.

The post-Triassic history of the Long Island-to-Hatteras portion of the Atlantic Coastal Region has been much more complex and interesting than has been supposed—even though more evidence is needed before present tentative conclusions can be adequately tested. However, present indications are that the physical evolution of the northern and central parts of the Atlantic Coastal area during post-Triassic time has progressed through several stages, as follows: (1) post-Triassic folding and faulting; (2) development of Jurassic gravel-coated plains like those of the present northwestern

Great Plains and eastern Rocky Mountain areas—with local hills rising several hundred feet above the bench surfaces; (3) pre-Lower Cretaceous uplift and deep trenching of the Jurassic gravel plains and re-development of a trellis drainage pattern in southeastern Pennsylvania and central New Jersey; (4) formation of coarse Lower Cretaceous delta deposits and fluviatile back-hills from the gravels and arkosic waste stripped from the Jurassic surfaces; (5) recurrent regional southeastward tiltings and subsidences coupled with local upwarpings along the axes of (still-existent) gravity-anticlines, with consequent recurrences of marine transgression and of valley back-fill; (6) recurrent warping and uptilting of most of the present emergent Coastal Region during Pleistocene and post-Pleistocene time.

The Jurassic ancestors of the Hudson, Delaware, Susquehanna, and Potomac drainage systems apparently flowed southeastward and eastward to points beyond the edge of the present Continental shelf. Due to erosional re-excavation and "resurrection," parts of these ancient stream-courses have been re-occupied by present-day drainage, northwest of the Fall line. Also due to a progressive compaction of the old valley-fills within the Coastal Plain region some of the smaller recent streams of south-central New Jersey have re-adopted the lines of this pre-Cretaceous drainage—even though they now flow in a direction reversing that of the original streams.

3. 9:50 J. R. LOCKETT, Columbus, Ohio.
Development of Structures in the Basin Areas of the Northeastern United States.

An area comprising Ohio, Indiana, Illinois, and northern Kentucky is considered as a distinct structural province. Stratigraphic evidence is cited to substantiate the premise that the major positive structural features are supported by the crystalline cores of pre-Cambrian mountain ranges and that the dominant crustal movement during the entire Paleozoic era was the subsidence of the intervening areas.

The importance of the weight of basins of accumulation and the results of their drag on the positive features are considered.

The Appalachian revolution is described as the culminating result of an era of subsidence. Lateral effects of orogenic stress are considered and evidence reviewed indicating that the province discussed was shielded from direct lateral pressure by the formation of the Pittsburgh-Hamilton basin.

Deformation through central Kentucky and southern Illinois is considered to have resulted from the westward expression of orogenic stress through greater thickness of sedimentary rocks.

Directions and probable extent of lines of weakness in the basement complex resulting from the conditions described are developed and the types of structures formed in sediments over them in Michigan, Illinois, and the western flank of the Pittsburgh-Huntington basin are postulated. Such structures are shown to be the results of differential subsidence and tension.

An experiment is described which duplicated in a general way the basal lines of weakness discussed.

The paper is intended to lay the groundwork for a new approach to the study of structural geology in this province.

4. 10:10 JOHN L. RICH, Professor of Geology, University of Cincinnati, Cincinnati, Ohio.
Submarine Sedimentary Features on the Bahama Banks and their Bearing on Distribution Patterns of Lenticular Oil Sands.

In flying from Miami to eastern Cuba, the route lay for a distance of 206 miles over the Bahama Banks. For the entire distance the sea bottom was visible through the water.

A striking pattern of bars and giant ripples was revealed that may aid in explaining the distribution pattern of certain lenticular oil and gas sands that seem to have been deposited at considerable distance off-shore.

The patterns on the Bahama Banks were photographed and mapped by photogrammetric methods. The pattern revealed is compared with that of the distribution of gas and oil sands in part of the Clinton sand area of Ohio. Remarkable similarity in pattern is revealed, but the scale of the Bahama Banks features is considerably smaller.

5. 10:20 F. A. VENING MEINESZ, Delegate for Science of the Netherlands Government; Professor of Geophysics, University of Utrecht, Holland. Cosmos Club, Washington, D. C.
Gravity in the East Indies and Its Interpretation.

The belt of strong negative anomalies in the East Indies can best be explained by assuming a downward buckling of the rigid crust, forming in that way a bulge of crustal material at the lower boundary of the crust of a cross section of 1500–2500 square kilometers. This stage of mountain-formation now reached in the East Indies suggests the following history for the development in geosynclines. The crust, floating on the plastic substratum is compressed by horizontal stress. If these stresses exceed the buckling limit of the crust, waves are formed of a few hundred kilometers length. In the downward waves sediments are deposited. If the compression further increases, one of them

gives away and buckles downward while the weaker sedimentary surface layers in this wave are crumpled and folded. In the adjoining wave—the oil syncline of Sumatra and Java—the crust is not buckling but the further compression of the waves gives the folding of the sedimentary filling.

In the main geosyncline the bulging downward will continue—possibly interrupted by periods of rest during which the area rises because of the tendency toward isostatic readjustment—till the compression finally decreases or till the concentration of crustal material restores the strength of the crust as a whole. At the end of the whole tectonic period, when the compression vanishes, the compressed belt can detach itself from the adjacent area because of the readjustment of the isostatic equilibrium. We thus obtain the stage of the mature folded mountain range.

The shallow earthquakes occurring near or in the belt of negative anomalies in the East Indies are the natural result of the crystal deformation. The volcanoes at the inside of the belt—especially at the inside of curved parts—as well as the earthquake-centers at intermediate depth in this same area are more difficult to explain; an attempt for an explanation will be made. Still more difficult is the explanation of the deep basins inside the volcanic island area in the eastern part of the East Indies which have sunk long after the last main folding period in the belt; also of the field of positive anomalies in these basins and of the deep earthquake-centers at the inside of the volcanic belt. Some of these phenomena may perhaps be explained by the assumption of convection currents started by the accumulation of heat in the belt because of the concentration there of crustal material which is more strongly radioactive than the deeper layers, but this explanation is certainly not completely satisfactory.

In the West Indies similar features and phenomena occur giving rise to similar explanations.

6. 11:00 HOWARD A. MEYERHOFF, Executive Secretary, American Association for the Advancement of Science, Washington, D. C.

Tectonic Features of the Greater Antilles.

The Greater Antilles comprise the northern non-volcanic segment of an elliptical mountain belt, with the non-volcanic ranges of Trinidad-Venezuela-Colombia-Panama forming the southern segment, and the volcanic belts of the Lesser Antilles and of Central America closing the eastern and western sides.

The oldest rocks in the West Indies are Jurassic. Although the Jurassic sediments contain some land-derived waste, attempts to establish a pre-Jurassic history have failed. The diastrophic record starts in post-Jurassic-pre-Cretaceous time, and thereafter sedimentation bears a closer relation to the rather localized diastrophic movements than to any decipherable regional pattern. The insular character of the Antilles has been a persistent feature, with the distribution of land areas, seas, and troughs shifting kaleidoscopically with vulcanism in the Cretaceous, and with the shifting sites of diastrophism at the ends of the Cretaceous, Eocene, mid-Miocene, and Pliocene. Major movements still continue, and Quaternary displacements are measurable in thousands of feet.

Antillean structures can best be explained as derivative from primary movements originating in the Andes and transmitted by successive northward thrusts, in part pivotal, across the competent Caribbean floor. Maximum displacement occurred in the west (Cuba), minimum in the east (Puerto-Rico, Virgin Islands). Pivotal movement created *en echelon* fold structures in Mesozoic orogenies and formed the east-west ramp system in Cenozoic time. In the latter, which now controls the distribution of deeps and island landforms, components of force have included compressive, lateral east-west, and vertical elements which, in combination, have acted somewhat fortuitously in space and time.

7. 11:30 F. A. SUTTON, Geologist, Creole Petroleum Corporation, Caracas, Venezuela.

Geology of the Maracaibo Basin, Venezuela.

The Maracaibo basin lies mainly in northwestern Venezuela and occupies the V-shaped depression lying between the diverging Andes de Merida and Sierra de Perija. On the southwest it extends slightly into eastern Colombia.

The area of the basin is approximately 23,572 square miles, of which 5,000 are covered by Lake Maracaibo, a large body of brackish water whose northern outlet is into the Caribbean Sea.

About 85 per cent of the basin floor is covered by the waters of the lake and recent deposits but the bordering highlands expose a geologic section extending from the pre-Cambrian to Recent. The petroliferous section has an over-all thickness of about 23,000 feet and extends from the base of the middle Cretaceous to the top of the middle Miocene. Of the fourteen formations comprising this sequence all but two are commercially productive at one place or another within the basin.

At present there are thirteen active fields in the basin. Eight of these are located in Venezuela and five in Colombia. In 1945 the total production for all fields was 221,730,000 barrels, approximately 9 per cent of the reported world's total. As of December 31, 1945, the cumulative total production was 2,634,428,000 barrels.

The Bolivar Coastal field, largest in the basin and one of the world's outstanding oil fields, produced 186,861,000 barrels during 1945 and as of December 31, 1945, had a total cumulative production of 2,188,339,000 barrels.

WEDNESDAY AFTERNOON, APRIL 3
North Ball Room, 3d Floor

TECTONICS AND OIL-FIELD PAPERS
2:00 p.m.—5:10 p.m.

GAYLE SCOTT AND LEE C. LAMAR, *Presiding*

1. 2:00 MAX BORNHAUSER, District Geologist, Continental Oil Company, Lafayette, Louisiana.
Marine Sedimentary Cycles of the Tertiary in the Mississippi Embayment.

The principles of marine cyclic deposition are discussed briefly and a classification of marine sedimentary cycles is presented. The principles are applied to the Tertiary section of the Mississippi embayment. Five major marine cycles are differentiated each representing a major transgression of the sea into this embayment.

Facies and thickness distribution of the older Tertiary cycles indicate the presence of a positive area (submarine plateau) in southeast Mississippi, which is bounded on the north and northwest by negative areas (synclines). Isopach studies also show a progressive expansion of this positive area north and northwest during Eocene time, with a corresponding north and northwestward shifting of the bordering synclinal areas. The theory is advanced that the southeast Mississippi plateau constitutes a part of the northern front of the Gulf of Mexico neutral plate, and that its progressive northward expansion is caused by a gradual rise and possible northwestward drift of this plate in connection with the Tertiary orogenic movements in the Greater Antilles. Epeirogenic movements in the Mississippi embayment and its borderlands are considered to be responsible for the different marine transgressions during the Tertiary. These movements reached a climax at the end of Jackson and during early Oligocene time, after which the sea retreated from the Mississippi embayment. Marine deposition during Miocene time is restricted to the Gulf Coast areas with one minor transgression occurring during the deposition of the *Heterostegina zone*.

2. 2:30 W. ARMSTRONG PRICE, Consulting Geologist, Corpus Christi, Texas.
Quaternary Diastrophic Activity on Coastal Plain of Western Gulf of Mexico.

Progressive deformation on all classes of structures present in region characterized Quaternary diastrophism, with all forces recognized continuously active. Deformation has increased under growing sediment load.

Types of deformation include: (1) regional (formational) tilt; (2) tilt on local sedimentary units, as sub-deltas and deltas; (3) rise and tilt on long strike flexures or anticlines, as the Fordyce-Rincon-Agua Dulce-Greta structural zone; (4) growth of faults of extension, as the Balcones, Mexia, and Luling zones; (5) rise of salt plugs even to late Recent; (6) deep-seated movements, probably gravitational, on buried structures manifested by seismicity. Late movements on faults at surface have resulted in formation of, or growth on, rift lines and scarps. Maximum vertical displacements known are: −2000 to −4000 feet on base of Pleistocene at coast, +152 feet on salt "dome" mounds, +45 feet on fault scarps and depressions.

Movements recognized are (1) gravitational adjustments: (a) on buried zones of folded and faulted pre-Tertiaries, (b) on unstable mother rock-salt bed of the salt plugs, (c) in sediments by compaction, (2) crustal yielding; (a) under sediment load, (b) along Mississippi structural trough across foundered Appalachian and Ouachita folded rocks.

To identify and date individual deformations requires (1) shallow subsurface stratigraphic and structural data, mostly lacking, (2) study of detailed and regional geomorphology: (a) on depositional surfaces, the study well advanced in Louisiana and the Mississippi "embayment," less in Texas, (b) on erosional surfaces, with little critical information. Outlines of geomorphology and structure of region are given, with discussion of methods and character of data. Conclusions are based on a sampling of the voluminous data available, both published and unpublished.

3. 2:45 MARTIN M. SHEETS, District Geologist, Stanolind Oil and Gas Company, Houston, Texas:
Diastrophic Activity, During Historic Time, in the Western Gulf Coastal Plain.

Evidence is at hand to indicate that the western Gulf Coastal plain is at present an area of active structural growth. This paper presents a collection of such evidence. Evidences of structural activity are discussed under six main classes: earthquakes, fissures, faults, regional warps, local subsidence, and pseudo-diastrophic features.

One major earthquake occurred in the vicinity of New Madrid, southeast Missouri, in 1811 and 1812. Much damage resulted and many geologic features were produced. A number of less intense earthquake shocks, which originated within the Gulf Coastal plain, have been recorded.

Fissures split trees in Lavaca County, Texas. Fissures which emitted small amounts of gas are reported from Nueces County, Texas. Peculiar faultlike fissures are described from Rankin County. Mississippi. The above three fissures occurrences are believed to be merely soil features. Fissures and faults are reported from the Mississippi alluvial valley. Fault movements are thought to be responsible for repeated breaking of a water main at Waco, Texas. Fault scarps are noticeable on the surface

in Lee County, Texas. The coast line in the vicinity of the Mississippi delta is believed to have been downwarped during historic time and an area on the western Florida coast has been elevated 1½ feet in the last 50 years.

Several cases of local subsidence have been reported on salt domes. A number of incidents are reported which are probably due to causes other than structural activity. The above evidence leads the writer to conclude that the Gulf Coast is at present an active area and that in this activity the force of gravity plays an important role.

4. 3:00 E. A. WENDLANDT, T. H. SHELBY, AND JOHN BELL, Geologists, Humble Oil and Refining Company, Tyler, Texas.

Hawkins Field, Wood County, Texas.

This paper presents a summary of the history, geology, and development of the Hawkins oil field, southeast Wood County, Texas, from its discovery in December, 1940, to September, 1945, when regulations of the Petroleum Administration for War were rescinded. Active field development followed completion of the discovery well, and although drilling was restricted by war emergency regulations, 415 oil wells have been completed, producing from the Woodbine formation at an average depth of 4,850 feet.

The Hawkins field occurs on a large northeastward-trending, faulted anticline situated near the north-central part of the East Texas geosynclinal basin. A major fault downthrown toward the northwest and trending northeast-southwest crosses the east part of the field. A pronounced gravity minimum indicates that the field is underlain by a deep-seated salt mass. Structural growth increases progressively with depth to the point where the Woodbine producing formation has structural closure approximating 1,200 feet. The Woodbine oil and gas reservoir, which is 5 miles long and 4 miles wide, underlies 8,774 acres. The estimated ultimate recovery from the oil productive area, which contains 8,372 acres, is 449,717,500 barrels. Cumulative production to September, 1945, was 43,134,613 barrels. The oil produced from the field is a predominantly asphaltic mixed-base crude with brownish black color, and the gravity ranges from 16° to 30°. Gas occurs above the Woodbine in the sub-Clarksville sand of the Eagle Ford formation, where porosity is developed.

Extensive coring and modern development methods have made possible an intensive study of the reservoir characteristics which may be unparalleled in any other field. Detailed reservoir information is, therefore, far superior to that available in any other Woodbine field in the East Texas basin. Surface mapping of geologic structure first directed attention to this area, where coredrill information later supplemented and confirmed the earlier surface work. It is noteworthy that until the time of the discovery of the field, the activities of the principal operator were not influenced by geophysics.

5. 3:30 D. A. MCGEE, Vice-President, and H. D. JENKINS, Chief Geologist, Kerr-McGee Oil Industries, Inc., Oklahoma City, Oklahoma.

West Edmond Oil Field, Oklahoma.

The West Edmond oil field of central Oklahoma, discovered on April 5, 1943, had produced more than 32 million barrels of oil from 704 wells through December 31, 1945. The field produced and ran 2,597,624 barrels of oil in November, 1945. Fifteen new wells were completed during December. On January 1, 1946, there were 30 drilling wells in the field. Through December 31, 1945, an estimated 46,000,000 MCF of gas had also been produced. Seventeen of the 704 wells produced oil from the "Bartlesville" sand of lower Pennsylvanian age; 687 wells produced oil from the Hunton limestone of Siluro-Devonian age. The field includes 30,000 proved acres and 1,500 to 2,000 semi-proved acres.

The field is located on the northern rim of the Anadarko basin of western Oklahoma. The local structure is monoclinal, dipping west into the basin at approximately 125 feet to the mile. Oil production in the Hunton limestone is the result of a wedgeout of the upper or Bois d'Arc member against the Nemaha ridge on the east and a regional wedgeout of the Hunton limestone on the north. Oil accumulation generally is in a coarsely crystalline limestone. The Bois d'Arc member reaches a maximum thickness of 140 feet on the west side of the field and wedges out completely toward the east, thus delineating the eastern limits of production. There is some minor oil production in the field from the lower or Chimneyhill member of the Hunton limestone where porosity is developed locally. In one small area in the northeastern part of the pool, oil is produced from the middle or Harragan-Henryhouse member due to a local development of porosity.

6. 4:00 CLAUDE E. LEACH, District Geologist, Tide Water Associated Oil Company, Ventura, California.

Geology of the Aliso Canyon Field, Los Angeles County, California.

The Aliso Canyon field is located in the eastern part of the Santa Susana Mountains, approximately 30 miles northwest from the center of Los Angeles, California. Oil is produced from the block beneath the folded Santa Susana thrust fault.

The complicated set of structural and stratigraphic conditions, pertinent to the accumulation

of oil is discussed. The Pliocene, Miocene, and Eocene series each contains a productive zone. Each series is separated from the other by an erosional unconformity with the result that the structure and productive limits of each oil zone are different.

7. 4:30 THEODORE A. LINK, Chief Geologist, Imperial Oil Limited, Toronto, Canada.
Tectonic Features of Western Canada.

Western Canada is divided into two general tectonic subdivisions: the "Pre-Cambrian shield" or basement complex, and the sedimentary "Cordilleran geosyncline."

Within the "Pre-Cambrian shield" is the shallow sedimentary basin termed the "Hudson's Bay basin."

The "Cordilleran geosyncline" is subdivided from east to west as follows: (a) "Moose Jaw basin" (Regina basin) which is the northerly extension of the "Williston" or "Dakota" basin of the United States, (b) "Sweet Grass-Battle River arch" divides the "Moose Jaw basin" from the (c) "Alberta syncline" in the southern part of western Canada which, through (d) the "Foothills belt," merges into (e) the "Rocky Mountain trough" of the "Cordilleran geosyncline."

In the northern part of western Canada (Northwest Territories and the Yukon), there is, in front (east) of the Rocky Mountains proper the (f) "Mackenzie Mountain salient" or bulge, in which structural conditions differing from those of the Rocky Mountains or Foothills are found.

The basin area of the Northwest Territories is subdivided into subsidiary units termed the (g) "Great Bear-Slave Lake basin" and the (h) "Mackenzie (Arctic) Delta basin" of relatively flat rocks overlapping the pre-Cambrian shield on the east and dipping beneath the folded mountains on the west.

A map of western Canada indicating the general outline and relationship of the tectonic features mentioned is presented.

THURSDAY MORNING, APRIL 4

Grand Ball Room

TRENDS AND DEVELOPMENTS SINCE 1941

9:15 a.m.—12:00 Noon

IRA H. CRAM AND ROY R. MORSE, *Presiding*

1. 9:15 TULSA GEOLOGICAL SOCIETY RESEARCH COMMITTEE: L. M. NEUMANN, Chairman; N. W. BASS, R. L. GINTER, S. F. MAUNEY, T. F. NEWMAN, CHARLES RYNIKER, AND H. M. SMITH. Paper to be read by N. W. BASS, Geologist, United States Geological Survey, Denver, Colorado.
Relationship of Crude Oils and Stratigraphy in Parts of Oklahoma and Kansas.

An investigation of several hundred analyses of crude oils from several Paleozoic zones, ranging from the upper part of the Arbuckle limestone of Ordovician age to sands of Pennsylvanian age in northeastern Oklahoma and southeastern Kansas, shows the following.

(1) The oils from 43 pools investigated in the oil-bearing beds associated with the unconformity at the top of the Arbuckle limestone contain 31 classes or varieties of oil, and the oils from 22 pools in the beds associated with the unconformity at the top of the "Mississippi lime" contain 13 classes or varieties of oils; many classes in each of these two zones are represented by only one pool and the other classes by only a few pools.

(2) The oils from 34 pools in the Bartlesville sand contain six classes of oil but at least three of the classes are in sand lenses, called Bartlesville, that are of different age and lie at different stratigraphic positions; the oils from 16 pools in the Bartlesville sand, distributed through an area 30 miles long and 12 miles wide, fall in one class.

(3) The oils from 33 pools in the Burbank sand, distributed through an area of 150 miles long and 1 to 35 miles wide, fall in one class.

(4) In Oklahoma each of seven oil-bearing zones younger than the Burbank sand, and in Kansas each of four such zones, contains a separate class of oil.

(5) Each of four pools in the Squirrel (Prue) sand, which is one of the seven zones mentioned under 4, contains a separate class of oil; inasmuch as the Squirrel (Prue) sand represents a series of lenses lying at various positions in a zone about 75 feet thick, the oil-bearing sands in the four pools probably are not precisely equivalent.

(6) In each field wherein oil pools occur in several zones the oil of each zone is unlike the oil in the other zones.

(7) The Bartlesville sand and the uppermost beds of the "Mississippi lime" contain similar oil in several pools in a narrow belt of country wherein the sand overlaps the "Mississippi lime."

These facts suggest that the environment of the source material may have determined the kind of oil of each oil pool. The local environment of beds in contact with the widespread unconformities at the top of the Arbuckle limestone and the top of the "Mississippi lime" would have been most variable; it is these beds that contain the greatest variety of oils. The Burbank sand is confined to a

thin stratigraphic zone; it was deposited in a narrow belt along the western shore of the Cherokee sea and the shoreline can be identified through a total length of about 150 miles. The environment during the time of deposition of the Burbank sand should have been similar all along the shore. It is significant, therefore, that the oils of all oil pools in the Burbank sand lenses of that belt are similar.

The structural movements that formed the many local domes, anticlines, synclines, and basins appear not to have changed the character of the oil, for the oil in the pools in the Burbank sand is similar throughout a distance of 150 miles wherein many types of folds are present. The present depth of burial likewise appears not to have altered the character of the oil, for the oil of the Burbank sand where it lies at a depth of 1,400 feet is similar to that found in the same sand at a detph of 2,900 feet or more. The low-gravity oils in several pools in the Arbuckle limestone in southeastern Kansas and in one pool in northeastern Oklahoma, that contain none of the lighter fractions common to most oils, have the appearance of weathered oils. They may have been weathered in post-Chattanooga time while the Chattanooga shale likely was being eroded from many small tracts and from at least one very large tract in northeastern Oklahoma and southeastern Kansas. The fact that the waters in the Arbuckle limestone in the area containing these pools appear to have been diluted by meteoric waters from the Ozark region has suggested to some that the oils were weathered by their contact with the waters.

2. 9:35 G. M. KNEBEL, Head of Exploration Division, Standard Oil Company (New Jersey), New York, N. Y. (Work sponsored and financed by the American Petroleum Institute.)
Progress Report on A. P. I. Research, Project 43, "The Transformation of Organic Material into Petroleum."

A brief history of A.P.I. Research Project 43 is presented, showing its origin as an outgrowth of the Parker Trask project (No. 4). The so-called "Geological Fence," prepared as a guide to the fundamental studies of Project 43, is briefly outlined.

Progress and results obtained by the three coordinated sub-projects (43-a, b, and c) are summarized, and comments on each are made, pointing to the more important unsolved problems toward the solution of which the future research work of Project 43 will be largely directed.

Theories of the origin of oil are discussed, and the need for other research work on the origin of oil, in addition to A.P.I. Project 43, is emphasized.

3. 10:00 R. CLARE COFFIN, Geophysical Coordinator, Stanolind Oil and Gas Company, Tulsa, Oklahoma.
Recent Trends in Geological-Geophysical Exploration, and Methods of Improving the Use of Geophysical Data.

Since 1942 the use of gravimetric methods has increased in the United States approximately 200 per cent, seismic methods 60 per cent, core drilling 100 per cent, and the magnetic investigations 70 per cent. The impact upon geological thinking because of this continued increase of geophysical effort is discussed. Full advantage offered by these methods and combinations of methods is not being made. A better use of the low-cost methods is pointed out. Tremendous increase in the use of the gravity method has not been made with corresponding improvement in the proper understanding of its possible use and its limitations. The use of the gravity method is discussed in some detail. A tremendous improvement in our geological thinking and a better use of geophysical data is possible by an education of district or "grass root" geologists in geophysical concepts and a freer use of this information. A trend in this direction is noted, but the need of an accelerated move in this trend is emphasized.

4. 10:20 STUART E. BUCKLEY, Head of Production and Research Division, Humble Oil and Refining Company, Houston, Texas.
Trends and Developments in Petroleum Production Engineering

This paper summarizes the important trends and developments in production engineering, particularly for the period since 1941. This period has had an important influence upon the trend of engineering development because of the fact that the high wartime rates of oil production afforded an opportunity for quantitative observation and evaluation of petroleum reservoir characteristics under controlled conditions.

It is the author's opinion that the most important development in petroleum engineering within recent years has been the inauguration of the transition from the qualitative to the quantitative stage. This transition is not complete but is in fact just sufficiently developed to be reaching the period of vigorous further growth and advancement. The groundwork for this quantitative stage has been built, and the future should bring a degree of quantitative engineering control far surpassing expectations of a few years ago. This trend is illustrated with examples of technically controlled development and operation of selected oil reservoirs, and the basic and applied research which forms the basis for the trend is briefly reviewed.

The suggestion is made that to keep pace with progress in the industry the technical man, engineer or geologist, must recognize the necessity of abandoning qualitative thinking and must adapt himself to the more difficult task of quantitative study. Those unable to accommodate themselves to this progressive change will lose ground in the same manner that others lost ground in many a manufacturing industry when the processes have advanced from art to science.

5. 10:40 M. T. HIGGS, Lane-Wells Company, Houston, Texas.
PAUL WEAVER, Gulf Oil Corporation, Houston, Texas.
Physical Measurements in Wells for Geologic Data.

The study of drilling reports, cores, and cuttings is recognized as basic in subsurface geological interpretation, and for some years it has also been agreed that additional important geological values can be obtained by measurements of the physical properties of the formations in place in a well. The authors describe the various measuring devices now in use for determining some of these physical properties, and the way in which the data measured are interpreted in subsurface work. They also review the present geographical distribution, within the United States, of the use of these devices.

6. 11:10 L. L. SLOSS AND S. R. B. COOKE, Montana School of Mines, Butte, Montana.
Spectrochemical Sample Logging of Limestones.

Visual examination and insoluble-residue analysis have not yielded uniformly satisfactory data for detailed differentiation and correlation of thick and unbroken sequences of carbonate rocks. The method here presented is an attempt to utilize quantitative spectrographic analysis for this purpose.

An external standard method which gave results reproducible within inherent sample error was used. Ca, Mg, Sr, Ba, Al, Ti, Fe, and Si were present in all samples, and Mn and V in some. For practical reasons S, P, Na, and K, undoubtedly present, could not be determined. The most useful elements appear to be Mg, Fe, Al, and Sr. When analyses of both surface samples and well cuttings are plotted against stratigraphic interval or well depth, the curves may be interpreted in terms of stratigraphic correlation and differentiation.

Standardization of the method is easy and the results are not dependent on the personal equation. Apart from initial expenditure for equipment, costs and time-consumption should be less than those required for foraminiferal and insoluble-residue analysis.

7. 11:25 C. E. DOBBIN, United States Geological Survey, Denver, Colorado.
Resume of Oil and Gas Developments in Canada and the United States in 1945.

8. 11:40 FREDERIC H. LAHEE, Chief Geologist, Sun Oil Company, Dallas, Texas.
Statistics of Exploratory Drilling, 1945.

For the first time since our studies on exploratory drilling began, we had an organized committee to compile the statistics on this subject for the past year. This is known as the "Committee on Statistics of Exploratory Drilling," composed of 23 members, and in many districts each member serving as chairman of a subcommittee. A great deal of credit is due to the many persons who assisted in assembling and classifying the data for the present report.

THURSDAY AFTERNOON, APRIL 4

North Ball Room, 3d Floor

REGIONAL AND OIL-FIELD PAPERS

2:00 p.m.—3:30 p.m.

EDWARD A. KOESTER AND BEN H. PARKER, *Presiding*

1. 2:00 C. R. THOMAS, JOHN W. HUDDLE, AND N. W. BASS, United States Geological Survey, Denver, Colorado. Published by permission of the director of the United States Geological Survey.
Rangely Oil Field, Rio Blanco County, Colorado.

Oil in the Weber sandstone of Pennsylvanian age was discovered in 1933 at a depth of 5,704 feet in the Rangely oil field of Rio Blanco, Colorado; after producing only about 8,000 barrels of oil, the well as shut in until September, 1943. About 45 wells have been completed in the Weber sandstone during the past 2 years and many additional wells are drilling in an area 7½ miles long and 2½ miles wide. The field is yielding a daily total of between 13,000 and 20,000 barrels of oil. A reserve of 225,000,000 barrels in a proved area of about 23,000 acres was estimated on February 15, 1946. The oil is transported through a 10-inch pipe line, laid in 1945, to Wamsutter, Wyoming, where it joins a trunk line, part of it going west to Salt Lake City, and part going east. It is noteworthy that many shallow wells in the field have obtained small yields of oil from fracture zones in the Mancos shale since 1902.

The Rangely oil field is on a large anticline whose structural closure is a little greater than 1,900

feet on the exposed Upper Cretaceous beds; the closing contour embraces an area of 100 square miles—20 miles long by 7½ miles wide at the widest place. The surface of the central part of the anticline forms a topographic basin, known as Raven Park, carved in the soft Mancos shale. The Park is surrounded by high rim rock formed by resistant sandstone in the Mesaverde group.

The top of the deep oil "pay"—the Weber sandstone—is encountered at depths ranging between 5,500 and 6,500 feet. The oil occurs in beds of very fine to fine-grained gray to buff partly micaceous and calcareous sandstone that is interbedded with non-oil-bearing red silty micaceous sandstone with partings of red shale. The oil-bearing beds are distributed through the uppermost 550 to 600 feet of the formation whose total thickness here is about 1,200 feet. The top of the oil "pay" in a well on the southeast flank of the anticline is 281 feet structurally lower than on the crest, and in a well on the northwest nose of the anticline is 725 feet lower than on the crest. No well in the field has encountered water in the Weber sandstone. The sand is tight in most wells. Some wells have been shot but others have been completed without shooting. The wells flow between 200 and 600 barrels of oil a day through ⅛ to ¾-inch chokes. The gas-oil ratios are from 300 to 350 cubic feet per barrel.

The Weber sandstone is somewhat younger than the Tensleep sandstone, which yields oil in many fields in Wyoming. The Weber is composed chiefly of red sandstone, shale and conglomerate, in part arkosic, and is barren of oil in deep wells on Douglas Creek, 20 miles south of the Rangely field. On the outcrops 30 to 35 miles northeast and northwest of the oil field the formation consists of massive beds of light gray to buff fine-grained well sorted irregularly calcareous sandstone that is slightly petroliferous at a few places.

The crude oil from the Weber sandstone at Rangely has a gravity of 34° to 35°; the percentage of sulphur is 0.68 per cent; and the content of residuum is about 27 per cent. The oil from the Mancos shale at Rangely has a gravity of 42° and is much less naphthenic than the oil from the Weber sandstone.

2. 2:30 LLOYD G. HENBEST, United States Geological Survey, Washington, D. C. (Published by permission of the director of the United States Geological Survey.)

Stratigraphy of the Pennsylvanian, in the West Half of Colorado and in Adjacent Parts of New Mexico and Utah.

In the southern Sangre de Cristo Range, New Mexico, a limestone that has been classed as the lower limestone member of the Sandia formation, Pennsylvanian, and that seemed to be barren of fossils, contains a Mississippian foraminifera characteristic of the Leadville limestone. This lower part of the Sandia is present locally in the Sandia Range and perhaps also in the Sierra Nacimiento, New Mexico. The lithic features of this lower part of the Sandia closely resemble those of the Leadville limestone in the San Juan Mountains, Colorado, and extend the San Juan Mountain facies of the Leadville about 150 miles southeastward.

Pennsylvanian deposition began at many, widely separated localities with clastics on a deeply weathered, uneven surface. The intensely red facies of these basal sediments (Molas formation) is especially characteristic of the sections in the San Juan Mountains and in the subsurface in the oil and gas fields on the south. This facies has also been observed at Glenwood Springs, Colorado, and locally in the Sandia Range, New Mexico. Correlative sediments in northwestern Colorado vary from red to gray and locally include coal-bearing terrestrial beds (lower part of the Morgan formation).

The deposition of the basal clastic sediments was followed by marine invasion in Morrow time as is indicated by the presence of Morrow Fusulinidae in the following: (1-a) the Glen Eyrie shale member of the Fountain formation at Colorado Springs and (1-b) the basal Fountain formation on the north; (2) the basal middle Morgan formation of northwestern Colorado and adjacent parts of the Uinta Range, Utah; (3) a part of the Beldon shale of Brill at Glenwood Springs, Salida, et cetera; (4) basal Hermosa formation, subsurface, northwestern New Mexico (but not in the San Juan Mountains on the north where the basal Hermosa is of Lampasas or Atoka age); and (5) Sandia formation in the Sierra Nacimiento and Sandia Range, New Mexico, Marine deposition continued and widened at many of the same localities into Lampasas or Atoka time—the age characterized by the *Fusulinella* fauna.

The most extensive and prolonged marine deposition occurred in the early half of Des Moines time (the zone characterized by *Fusulina* and *Wedekindellina* and locally may have continued into later Des Moines time. The following stratigraphic units belong in the early Des Moines; (1) all but the base of the Hermosa in the San Juan Mountains; (2-a) lower part (at least) of the Maroon formation, Ten Mile District near Leadville and (2-b) upper part (at least) of the McCoy formation of Roth on the northwest; (3) Melton's Veta Pass limestone member of the Sangre de Cristo formation, La Veta Pass, Colorado; (4) upper part of the Morgan formation in northwestern Colorado; and (5) variously, according to locality, upper parts of the Sandia and lower parts of the Madera formation in northern New Mexico. The pre-eminence and wide distribution of marine deposition in Des Moines time in the Rocky Mountain region is an interesting parallel with a similar situation in Eurasia.

Though marine sediments of Missouri and Virgil age are present in certain basins in surrounding areas and in mountains in New Mexico, wherever rocks of possibly equivalent age exist in the mountains of Colorado they generally have a redbeds facies, some perhaps reaching immense thicknesses.

In northwestern Colorado the marine facies of Morrow age appears to persist westward into Utah, but the overlying marine beds of Lampasas or Atoka and of Des Moines age appear to grade laterally into a facies classed with the Weber sandstone.

Though principal divisions of the Pennsylvanian are represented by marine sediments in the Rocky Mountain region of Colorado and northern New Mexico, the successions are rather generally replete with interruptions except within the lower half of the Des Moines in Juniper Mountain in northwestern Colorado and subsurface in northwestern New Mexico.

3. 2:55 WILSON M. LAIRD, State Geologist, North Dakota Geological Survey, Grand Forks, North Dakota.
LAURENCE L. SLOSS, Associate Professor of Geology, Montana School of Mines, Butte, Montana.
Devonian Stratigraphy in Montana.

As part of the wartime oil and gas investigation sponsored by the Geological Survey and the Montana Bureau of Mines and Geology, the Devonian stratigraphy of northwestern and central Montana was studied in detail. Studies were also made of cuttings from deep oil tests on the Sweetgrass arch.

It was found that as far as the surface stratigraphy in northwestern Montana is concerned the strata referred to the Jefferson formation could be divided into three units, arbitrarily labelled Da, Db, and Dc. The upper unit Da consists of Da_1 an evaporite solution breccia, consisting largely of large blocks of brown dense to saccharoidal dolomite in a matrix of dense and in places saccharoidal limestone. The lower part of this unit (Da_2) is coarsely saccharoidal dolomite. On the Sweetgrass arch in the subsurface this unit is represented by an interbedded anhydrite and limestone sequence termed the Potlatch anhydrite.

Unit Db is dense limestone which apparently is present in Montana except almost everywhere in northwestern and central Montana. Unit Dc is red shale, "mudstone," sandstone, and shaly dolomite and limestone sequence. In the Lewis and Clarke Range this unit discomformably rests on the Cambrian. In central Montana, this unit is in apparent transition with the Cambrian Dry Creek shale. The significance of the contact is discussed.

In terms of the type section near Logan, Montana, the unit herein designated Db belongs to the limestone member of the Jefferson formation. Units Da_2 and the lower part of Da_1 are correlated with the dolomite member of the Jefferson. The upper part of unit Da_1 is correlated with the Three Forks shale, including the "Sappington" sandstone.

4. 3:10 MARCELLUS H. STOW, Professor of Geology, Washington and Lee University, Lexington, Virginia. (Presented with permission of the Geological Society of America. Work done under grant from Penrose Bequest of that Society.)
Dating Sedimentation, Vulcanism, and Orogeny by Heavy Minerals in Beartooth Region, Montana.

The paper represents a step in the demonstration of the chronologic relationship between time of mountain uplift, time of notable volcanic activity, and time of accumulation of basin-fill sediments in the Crazy Mountain syncline and Bighorn basin.

The results of this investigation show that the stratigraphic units mapped as Hell Creek, Tullock, Lebo, and Tongue River from significant fossil vertebrate localities in the vicinity of Polecat Bench and Heart Mountain, Wyoming, are correlative with units designated as Hell Creek, Bear, Lebo No. 1 and Lebo No. 2, and Melville, respectively, in the Crazy Mountain syncline.

The agglomerates along the Yellowstone River are overlain by shales and sandstones of the Hell Creek. From place to place they truncate beds of Claggett, Judith River, Bearpaw, and possibly Lennep, or are interfingered with these formations. This indicates a period of extensive volcanic activity along the northern front of the Beartooth Range during late Upper Cretaceous.

Sedimentary petrographic studies show distinctly different mineral assemblages east and west of a line between Roscoe and Reed Point, Montana—representing a sedimentation divide. The minerals found in the area west of the divide are from a source in sedimentary and volcanic rocks; those in the area east of the divide are from sedimentary and metamorphic rocks. Therefore, this evidence implies that as early as Hell Creek time, two depositional basins had been established, corresponding with the present area of the Crazy Mountain syncline and the northward extension of the Bighorn basin. It also indicates that the crystalline core of the northwestern part of the Beartooth Range had not been stripped of its cover of Paleozoic sedimentary rocks by the close of Tongue River time.

PAPERS "BY TITLE"

1. ROBERT L. BATES, Oil and Gas Division, New Mexico Bureau of Mines and Mineral Resources, Socorro, New Mexico.
Geologic Contribution of a State to the Oil Industry.

An outline is given of the ways in which New Mexico, through its Bureau of Mines and Mineral

Resources, has contributed geological information and service to the oil industry, from establishment of the Bureau in 1937 to the present time. In particular, detailed records kept since the beginning of 1941 are included to show in precise terms what has been done over the past five years. Matters discussed include the publication of reports, both on oil and gas and on related geologic subjects; the distribution of well logs; the building-up of a file of well samples and sample descriptions; and cooperation with the United States Geological Survey in its work on oil and gas investigations in New Mexico. The paper summarizes those contributions in which New Mexico seems to have been successful, and indicates the ways in which it is hoped to make improvement or innovations.

2. JOHN C. MAHER, United States Geological Survey, Tulsa, Oklahoma.
Subsurface Paleozoic Stratigraphy of Southeastern Colorado. (Published by permission of the director of the Geological Survey, United States Department of the Interior.)

Stratigraphic investigations designed to assist in the search for oil and gas in western Kansas, eastern Colorado, and parts of the adjacent states were begun in 1943 by the Geological Survey, United States Department of the Interior, with the primary objective of correlating the subsurface Paleozoic rocks in these areas with the formations in the oil fields of central Kansas. The results of the investigations in southeastern Colorado are summarized in this paper. The principal structural features of the area, the Las Animas arch and the Sierra Grande uplift, are discussed in relation to the stratigraphy. Cross sections and distribution maps show Ordovician, Mississippian, Pennsylvanian, and lower Permian beds wedging out southward on the flank of the Sierra Grande uplift. Simpson sedimentary rocks are present in the surrounding area but do not appear to be present north of the Arkansas River where the Viola limestone rests on the Arbuckle limestone. The Viola limestone thins gradually westward and is absent in the western part of the area. This disappearance of the Viola westward caused the Keokuk, Burlington, and Misener sequence in the early wells to be identified erroneously as the Viola and Simpson interval. Mississippian rocks ranging from Kinderhook to Meramec in age are present throughout the area north and east of the Sierra Grande uplift. Regionally these rocks thin northward; the Ste. Genevieve limestone marks the top in the south and Spergen limestone in the north. Beds of probable Morrow age overlie the Mississippian rocks wherever they are present. The lower Pennsylvanian rocks are thickest in the western part of the area, where practically all of the Pennsylvanian and Permian beds are clastics.

3. GEORGE V. COHEE, United States Geological Survey, Ann Arbor, Michigan. (Published with the permission of the director of the Geological Survey, United States Department of the Interior.)
Cambrian and Ordovician Rocks Penetrated by Recent Wells Drilled in Southeastern Michigan.

All of the wells drilled to pre-Cambrian rocks in the southern Peninsula of Michigan are located in five counties in the southeastern part of the state bordering the province of Ontario, Canada. The depth to pre-Cambian in this area ranges from 3,300 feet in Lenawee County to 6,400 feet in Washtenaw County.

The thickness of middle Ordovician rocks penetrated in these wells varies from 660 feet in Lenawee County to 965 feet in St. Clair County, and of upper Ordovician rocks from 585 feet in Washtenaw County to 750 feet in Lenawee County. Lower Ordovician rocks have not been found east of Livingston County. A well on the Howell anticline, near the center of Livingston County, drilled 40 feet of St. Peter sandstone and was abandoned without penetrating the entire thickness of the sandstone. Small areas of commercial oil production in the upper part of the Trenton limestone of middle Ordovician age have been found in Lenawee, Monroe, and Wayne counties, and oil is produced from middle Ordovician rocks in Kent County, southwestern Ontario.

Rocks of upper Cambrian age underlie middle Ordovician rocks and rest on pre-Cambrian rocks in a large part of southeastern Michigan. The thickness of Cambrian rocks varies from 1,160 feet in Washtenaw County to 140 feet in St. Clair County. This variation in thickness is due to the unconformity at the base of middle Ordovician rocks which was brought about by uplift and erosion at the close of lower Ordovician time. Cambrian rocks are missing in parts of Kent, Lambton, and other counties in southwestern Ontario, and in these places middle Ordovician rocks overlie pre-Cambrian rocks. Shows of gas have been reported from the upper part of the Mt. Simon sandstone, of upper Cambrian age, in some of the wells in southeastern Michigan and showings of oil and gas have been found in Cambrian rocks in some wells in parts of southwestern Ontario where the rocks are present.

PAPERS ON S.E.P.M. PROGRAM

SEDIMENTATION

1. 9:00 PAUL D. KRYNINE, School of Mineral Industries, Pennsylvania State College, State College, Pennsylvania.
Development of Porosity in Reservoir Rocks.
2. 9:30 F. J. PETTIJOHN, University of Chicago, Chicago, Illinois.
Carbonate Inclusions in Secondary Outgrowths on Clastic Quartz in Limestone.

3. 9:50 ADA SWINEFORD, State Geological Survey of Kansas, Lawrence, Kansas.
FRANCES SWINEFORD, Department of Education, University of Chicago.
Comparison of Three Sieve Shakers.
4. 10:00 E. C. DAPPLES, Northwestern University, Evanston, Illinois.
Some Physical Properties of Glacial Tills from Northeastern Illinois.
5. 10:15 PAUL D. KRYNINE AND RUTH O. HOTTON, School of Mineral Industries, Pennsylvania State College, State College, Pennsylvania.
Sediments of the United States.
6. 10:30 A. K. MILLER AND WALTER YOUNGQUIST, University of Iowa, Iowa City, Iowa.
A Giant Ammonite from the Cretaceous of Montana.
7. 10:45 HORACE G. RICHARDS, Academy of Natural Sciences, Philadelphia, Pennsylvania
Studies on Macrofossils from Deep Wells along the Atlantic Coast.
8. 11:00 HEINZ A. LOWENSTAM, Illinois State Geological Survey, Urbana, Illinois.
Root Morphology and Mode of Attachment of Crotalocrinites.
9. 11:15 F. B. PLUMMER, University of Texas, Austin, Texas.
Types and Origins of Central Texas Limestones.
10. CHARLES E. DECKER, University of Oklahoma, Norman, Oklahoma.
Additional Graptolites and Hydrozoan-Like Fossils, Big Canyon, Oklahoma. (By title.)

GENERAL

1. WILBERT H. HASS, United States Geological Survey.
Conodont Faunas from Upper Devonian and Lower Mississippian Formations of Ohio.
2. 2:15 HAROLD W. SCOTT, DORIS NODINE, AND EDWARD ZELLER, University of Illinois, Urbana, Illinois. (Paper to be read by EDWARD ZELLER.)
Wall Structure of Endothyra Baileyi
3. 2:25 LLOYD G. HENBEST, United States Geological Survey, Washington, D. C. (Published by permission of the director of the United States Geological Survey.)
The Morrow Group, Pennsylvanian, of Washington County, Arkansas.
4. 2:45 CHALMER L. COOPER, Illinois Geological Survey, Urbana, Illinois. (Published with permission of the chief of the Illinois State Geological Survey.)
Upper Kinkaid (Mississippian) Microfauna.
5. 3:00 JAMES STEELE WILLIAMS, United States Geological Survey, Washington, D. C. (Published by permission of the director of the United States Geological Survey.)
Mississippian of Southeastern Alaska.
6. 3:20 E. R. APPLIN, United States Geological Survey, Tallahassee, Florida. (Published by permission of the director of the United States Geological Survey.)
A New Foraminiferal Fauna from Beds of Lewisville (Early Upper Cretaceous) Age in Texas.
7. 3:30 MORTON B. STEPHENSON, Stanolind Oil and Gas Company, Houston, Texas. (Paper to be read by J. B. GARRETT.)
Weches Eocene Ostracoda from Smithville, Texas.
8. 3:40 FREDERICK M. SWAIN, Pennsylvania State College, State College, Pennsylvania.
Middle Mesozoic Non-Marine Ostracoda.
9. 3:50 H. B. STENZEL, University of Texas, Bureau of Economic Geology, Austin, Texas.
Gryphaeas.

PERMIAN

1. 9:00 RAYMOND C. MOORE AND RUSSELL M. JEFFORDS, University of Kansas, Lawrence, Kansas.
New Permian Corals.
2. 9:15 J. HARLAN JOHNSON, Colorado School of Mines, Golden, Colorado.
Notes on Some Permian Algae.
9. 9:25 RALPH H. KING, United States Geological Survey, Washington, D. C. (Published by permission of the director of the Geological Survey, United States Department of the Interior.)
Sedimentation in Permian Castile Sea.
4. 9:40 HORACE D. THOMAS, Geological Survey of Wyoming, and MAX L. KRUEGER, Union Oil Oil Company of California, Laramie, Wyoming.
Permian Stratigraphy of Uinta Mountains, Utah.
5. 9:55 RAYMOND C. MOORE, Director, Geological Survey of Kansas, Lawrence, Kansas. (Published by permission of the director of the Geological Survey, United States Department of the Interior.)
Strata of Wolfcamp and Leonard Age in North-Central Texas Region.
6. 10:10 JOHN W. SKINNER, Humble Oil and Refining Company, Midland, Texas.
Correlation of Permian of West Texas and Southeast New Mexico.

7. 10:30 E. RUSSELL LLOYD, Consulting Geologist, Midland, Texas.
Alternative Permian Correlations—A Discussion.
8. 10:40 PHILIP B. KING, Geologist, Geological Survey, United States Department of the Interior. (Published by permission of the director of the Geological Survey.)
Permian Correlations—A Discussion.
9. 11:00 Open Discussion.
1. Preceding papers and Permian correlation in general.
2. Permian problems and the Permian volume.

PAPERS ON S.E.G. PROGRAM

GENERAL

1. W. R. MITCHELL, Vice-President, National Geophysical Company, Inc.
F. P. WIPFF, Senior Engineer, National Geophysical Company, Inc.
Paper presented by title.
Q Meter for Low Frequency Reactor Measurements.
2. PAUL F. HAWLEY, Consolidated Engineering Corporation.
Geophysical Contributions to Vibration Measurements and Micro-Chemistry.
3. IRWIN ROMAN.
An Observational Method to Overcome Zero Drift Error in Field Instruments.
4. F. J. WILLIAMS, Geophysical Service, Inc.
Notes on Shot-Point Procedure.
5. D. H. WEINSTEIN, Assistant Chief Geophysicist, Superior Oil Company.
Optics of Recording Oscillographs.
6. EUGENE FROWE, Chief Physicist, Robert H. Ray Company.
A Diving Bell for Underwater Gravimeter Operation.
7. DARWIN S. RENNER, Superintendent of Electronics Division, Geophysical Service, Inc.
Seismometer Engineering.
8. FRANK RIEBER, Rieber Research Laboratory.
Uses of the Vibrotron in Geophysics.
9. R. L. CONGDON, Research Engineer.
Paper presented by title.
The Design and Testing of a Versatile Dynamic Seismometer.
10. L. W. GARDNER, Gulf Research and Development Company.
Vertical Velocities from Reflection Shooting.
11. G. L. BEYER, JR., AND WARD SHIPPARD, JR., Naval Ordnance Laboratory, Washington, D. C.
Sponsored by Milton B. Dobrin.
A Recording Six-Trace Cathode Ray Oscillograph.
12. GLENN J. BAKER, Geophysicist, William M. Barret, Inc.
Paper presented by title.
Dimensions and Units of Electromagnetic Quantities.
13. H. M. EVJEN, Vice-President, Elflex Company.
W. B. LEWIS, President, Elflex Company.
Paper presented by title.
Further Experimental Proofs of Working Depths for Low-Frequency Commutated Currents.
14. C. Y. FU, Consulting Research Geophysicist, United Geophysical Company.
Paper presented by title.
Studies of Seismic Waves: Propagation of Elastic Waves in the Neighborhood of a Free Boundary.
15. R. MAURICE TRIPP, Assistant to the President, Geotechnical Corporation, Research Laboratory.
CHARLES C. O'BOYLE, Research Geophysicist, Geotechnical Corporation, Research Laboratory.
Paper presented by title.
Beta Activity of Some Carbonaceous Materials.
16. ALFRED WOLF, Geophysical Research Corporation.
Paper presented by title.
Electric Field of an Oscillating Dipole on the Surface of a Two-Layer Earth.

CASE HISTORIES

1. WALTER J. OSTERHOUDT, Supervisor of Geophysical Operations, Houston Division, Gulf Research and Development Company.
The Seismograph Discovery of an Ancient Mississippi River Channel.
2. WILLIAM C. WOOLEY, Magnolia Petroleum Company.
Geophysical History of the La Gloria Field, Jim Wells and Brooks Counties, Texas.

3. HOLLAND C. MCCARVER, Chief Geophysicist, Seaboard Oil Company of Delaware.
LLOYD G. WEST, District Geologist, Seaboard Oil Company of Delaware.
The Geology and Geophysics of the Odem Oil Field, San Patricio County, Texas.
4. A. P. WENDER, Seismic Computor, Humble Oil and Refining Company.
A Geophysical History of the Lovell Lake Oil Field, Jefferson County, Texas.
5. L. L. NETTLETON, Gulf Research and Development Company.
Geophysical History of Typical Mississippi Salt Domes.
6. STUART W. SEELEY, Radio Corporation of America.
Typical Mississippi Salt Domes.
7. D. M. CHOATE, Geologist-Geophysicist, Atlantic Refining Company.
O. C. CLIFFORD, JR., Chief Geophysicist, Atlantic Refining Company.
Paper presented by title.
Seismic Surveys of Neale Field, Beauregard Parish, Louisiana.
8. WILLIAM B. HEROY, Director of Foreign Production, Petroleum Administration for War, Washington, D. C.
Foreign Geophysical Activities in 1945.

GENERAL

1. J. BRIAN EBY, Consulting Geologist, Houston, Texas.
The Status of Geophysics.
2. E. A. ECKHARDT, Gulf Research and Development Company.
The Airborne Magnetometer.
3. MAURICE EWING, Woods Hole Oceanographic Institution.
Underwater Prospecting
4. D. C. SKEELS, Research Geophysicist, Standard Oil Development Company.
Ambiguity in Gravity Interpretation.
5. E. E. ROSAIRE, Subterrex.
General Consideration for the Premium Technological Discovery of Petroleum.
6. C. HEWITT DIX, Vice-President, United Geophysical Company.
Efficiency in Exploration. I. General.
7. SYLVAIN J. PIRSON, Pennsylvania State College.
Disturbing Factors in Geochemical Prospecting.
8. LEONARD J. NEUMAN, Consulting Engineer, Houston, Texas.
Multiple Refraction Shooting in Southern Florida.
9. H. L. SCHIFLETT, Manager, States Exploration Company.
Quantitative Interpretation of Gravimetric Data.
10. HERBERT DAWSON, Petty Geophysical Engineering Company.
The Planning of a Foreign Geophysical Operation.
11. C. HEWITT DIX, Vice-President, United Geophysical Company.
Paper presented by title.
Efficiency in Exploration. II. Refraction Profiling.

MINUTES, THIRTY-FIRST ANNUAL BUSINESS MEETING STEVENS HOTEL, CHICAGO, ILLINOIS APRIL 2, AND 4, 1946

M. G. CHENEY, *presiding*

The meeting was called to order at 12:30 P.M., Tuesday, April 2, 1946, by M. G. Cheney, president.

1. *Resolutions committee.*—The president appointed a resolutions committee composed of Harold W. Hoots, chairman, Frank Gouin, and Henry N. Toler.

2. *Nomination of officers.*—The president called for nomination of officers of the Association for the ensuing year. The following nominations were made.

For president: EARL B. NOBLE, Los Angeles, California, nominated by George Sawtelle.

Motion to close the nominations was duly seconded, put, and carried.

Motion to instruct the secretary to cast the unanimous ballot for Earl B. Noble as president, duly seconded, put, and carried.

For vice-president: D. PERRY OLCOTT, Houston, Texas, nominated by Ralph A. Liddle.

Motion to close the nominations was duly, seconded, put, and carried.

Motion to instruct the secretary to cast the unanimous ballot for D. Perry Olcott as vice-president, duly seconded, put, and carried.

For secretary-treasurer: EDWARD A. KOESTER, Wichita, Kansas, nominated by Glenn H. Bowes.

Motion to close the nominations was duly seconded, put, and carried.

Motion to instruct the secretary to cast the unanimous ballot for Edward A. Koester as secretary-treasurer, duly seconded, put, and carried.

For editor: GAYLE SCOTT, Fort Worth, Texas, nominated by Fred H. Moore.

Motion to close the nominations was duly seconded, put, and carried.

Motion to instruct the secretary to cast the unanimous ballot for Gayle Scott as editor, duly seconded, put, and carried.

Meeting recessed at 12:45 P.M., April 2, until 3:40 P.M., April 4, 1946.

The recessed meeting was called to order by president Cheney at 3:40 P.M.

3. *Reading of minutes.*—It was moved, seconded, and carried that the minutes of the last annual meeting held at Tulsa, Oklahoma, March 27, 1945, be not read since they have been published in the *Bulletin* (May, 1945, pp. 573–609).

4. *Report of business committee.*—The report of the business committee, Robert W. Clark, chairman, was read by C. L. Moody, vice-chairman (Exhibit I).

It was moved by J. S. Hudnall and seconded by Leo R. Newfarmer that the recommendations of the business committee concerning changes in the constitution and by-laws as recommended in the report of the committee on the method of election of officers be adopted as read. Aye: 58. No: 16.

It was moved by George S. Buchanan, seconded by Ed. W. Owen, and unanimously carried that the remainder of the report of the business committee be adopted as read.

5. *Report of officers.*—The reports of president M. G. Cheney, secretary-treasurer Edward A. Koester, and editor Gayle Scott were read (Exhibits II, III, IV).

6. *Report of resolutions committee.*—The report of the resolutions committee was read by Frank Gouin (Exhibit V).

It was moved, seconded, and carried that the report of the resolutions committee be accepted.

7. Officers for the coming year were introduced.

8. It was moved, seconded, and carried that the untiring efforts of the retiring officers be acknowledged by a standing vote.

(The following reports appear as exhibits as part of the minutes.)

I. Business, Robert W. Clark, chairman
II. President, Monroe G. Cheney
III. Secretary-treasurer, Edward A. Koester
IV. Editor, Gayle Scott
V. Resolutions, Harold W. Hoots, chairman
VI. Distinguished lectures, Fred W. Moore, chairman
VII. Trustees of Research Fund, chairman
VIII. Classification and Nomenclature of Rock Units, C. W. Tomlinson, chairman
IX. National service, Fritz L. Aurin, chairman
X. Applications of geology, J. Brian Eby, chairman
XI. Medal award, Frank R. Clark, chairman
XII. Boy Scout literature, Max W. Ball, chairman
XIII. Research, Shepard W. Lowman, chairman
XIV. Geologic names and correlations, John G. Bartram, chairman
XV. Statistics of exploratory drilling, F. H. Lahee, chairman
XVI. Publication, C. E. Dobbin, chairman
XVII. National Research Council Division of Geology and Geography, Monroe G. Cheney, representative

The meeting adjourned at 5:25 P.M.

M. G. CHENEY, *president* EDWARD A. KOESTER, *secretary*

EXHIBIT I. REPORT OF BUSINESS COMMITTEE

The business committee recommends to the annual business meeting that the following proposals be adopted.

I. *Distinguished Lecture Committee.*—

The executive committee recommends and the business committee has approved the following changes in the by-laws.

1. Change the by-laws, Article VI, Section 1, first paragraph, to read as follows:

"There shall be the following standing committees; business committee; research committee; committee on geological names and correlations; committee on applications of geology; committee for publication; finance committee; committee on statistics of exploratory drilling; trustees of revolving publication fund; trustees of research fund; medal award committee; and DISTINGUISHED LECTURE COMMITTEE."

2. Add a new section to the by-laws, Article VI, as follows:

"DISTINGUISHED LECTURE COMMITTEE"

"SECTION 13. THE PURPOSE OF THE DISTINGUISHED LECTURE COMMITTEE IS TO ARRANGE, CONDUCT, AND MANAGE A SERIES OF SELF-SUSTAINING, NON-PROFIT LECTURE TOURS AMONG AFFILIATED SOCIETIES AND ASSOCIATION SECTIONS BY OUTSTANDING SPEAKERS ON TIMELY SUBJECTS. THE COMMITTEE SHALL CONSIST OF SEVEN MEMBERS UNLESS A DIFFERENT NUMBER IS AUTHORIZED BY THE EXECUTIVE COMMITTEE."

II. *Method of Election of Officers.*—

The business committee recommends the following changes in the constitution and by-laws:

1. Change the constitution, articles IV, V, and VI to read as follows:

ARTICLE IV. OFFICERS AND THEIR DUTIES

"SECTION 2. The officers shall be elected annually from the Association at large BY MEANS OF SECRET MAILED BALLOT IN THE FOLLOWING MANNER: THE NOMINATING COMMITTEE SHALL NOMINATE ONE OR MORE CANDIDATES FOR EACH OFFICE, AND ITS NOMINATIONS SHALL BE PUBLISHED IN THE SEPTEMBER *Bulletin*. ADDITIONAL NOMINATIONS MAY BE MADE BY WRITTEN PETITION OF FIFTY, OR MORE, MEMBERS IN GOOD STANDING RECEIVED AT ASSOCIATION HEADQUARTERS NOT LATER THAN NOVEMBER 15. THE EXECUTIVE COMMITTEE SHALL THEN PREPARE A PRINTED BALLOT, LISTING THE CANDIDATES FOR EACH OFFICE, AND ONE BALLOT SHALL BE MAILED TO EACH MEMBER AS SOON AFTER NOVEMBER 15 AS POSSIBLE. BALLOTS RETURNED TO ASSOCIATION HEADQUARTERS ON OR BEFORE JANUARY 31 SHALL BE PLACED AS RECEIVED IN A LOCKED BALLOT BOX AND PROMPTLY AFTER JANUARY 31 THE BALLOT COMMITTEE SHALL OPEN THE BALLOT BOX AND COUNT THE BALLOTS. BALLOTS OF DELINQUENT MEMBERS SHALL NOT BE COUNTED. A MAJORITY OF ALL VOTES CAST FOR AN OFFICE IS NECESSARY FOR ELECTION. IF THERE ARE THREE OR MORE NOMINEES FOR ANY OFFICE, A PREFERENTIAL FORM OF BALLOT SHALL BE USED. IN CASE OF A TIE VOTE, THE EXECUTIVE COMMITTEE SHALL CAST ONE ADDITIONAL DECIDING VOTE. Each candidate, when voted for as a candidate for the particular office for which he is nominated, shall be thereby automatically voted for as candidate for the executive committee for one year, except that candidates for the presidency shall be automatically voted for as candidates for the executive committee for two years.

"SECTION 4. The president shall be the presiding officer at all meetings of the Association, shall take cognizance of the acts of the Association and of its officers, shall appoint such committees as are required for the purposes of the Association, EXCEPT THE NOMINATING COMMITTEE, and shall delegate members to represent the Association. He may, at

his option, serve on and be chairman of any committee, EXCEPT THE NOMINATING COMMITTEE.

"SECTION 8. The officers shall assume the duties of their respective offices immediately after the annual meeting, WHICH FOLLOWS THEIR ELECTION.

ARTICLE V. EXECUTIVE COMMITTEE—MEETINGS AND DUTIES

"SECTION 3. The executive committee shall consider all nominations for membership and pass on the qualifications of the applicants; shall have control and management of the affairs and funds of the Association; shall determine the manner of publication and pass on the material presented for publication; shall designate the place of the annual meeting: SHALL APPOINT THE NOMINATING COMMITTEE AND ITS CHAIRMAN; AND SHALL BE IN CHARGE OF THE ANNUAL ELECTION OF OFFICERS AND DECIDE ELIGIBILITY AND OTHER QUESTIONS PERTAINING TO THE ELECTION. They are empowered to establish a business headquarters for the Association, and to employ such persons as are needed to conduct the business of the Association. They are empowered to accept, create, and maintain special funds for publication, research, and other purposes. They are empowered to make investments of both general and special funds of the Association. Trust funds may be created, giving to the trustees appointed for such purpose, such direction as to investments as seem desirable to the executive committee to accomplish any of its objects and purposes, but no such trust funds shall be created unless they are revocable upon ninety (90) days' notice.

ARTICLE VI. MEETINGS

"The Association shall hold at least one stated meeting each year, which shall be the annual meeting. This meeting shall be held in March or in April at a time and place designated by the executive committee. At this meeting the election of members shall be announced, the proceedings of the preceding meeting shall be read, Association business shall be transacted, scientific papers shall be read and discussed and officers for the ensuing year shall be ANNOUNCED."

2. Provisionally amend the by-laws, Article VI, as follows, such amendments to become a part of the by-laws only on approval by the membership of the above proposed constitutional amendments.

BY-LAWS

ARTICLE VI. COMMITTEES

(Section 1, 3rd paragraph) "In addition to the aforesaid standing committees, THE EXECUTIVE COMMITTEE SHALL APPOINT ANNUALLY A NOMINATING COMMITTEE AND ITS CHAIRMAN, and the president shall appoint annually a ballot committee, and annually or semiannually a resolutions committee, and such special committees as the executive committee may authorize. Special committees shall be appointed for a term of one year. The president shall designate the chairmen of such committees.

(New Section)

NOMINATING COMMITTEE

"SECTION 14. THE PURPOSE OF THE NOMINATING COMMITTEE IS TO NOMINATE CANDIDATES FOR THE ASSOCIATION OFFICES AS PROVIDED IN THE CONSTITUTION. THE COMMITTEE SHALL CONSIST OF A CHAIRMAN AND FOUR OTHER MEMBERS APPOINTED BY THE EXECUTIVE COMMITTEE TO SERVE ONE YEAR. AT LEAST TWO MEMBERS OF THE NOMINATING COMMITTEES SHALL BE PAST OFFICERS OF THE ASSOCIATION.

(New Section)

BALLOT COMMITTEE

"SECTION 15. THE FUNCTION OF THE BALLOT COMMITTEE IS TO COUNT THE BALLOTS RECEIVED IN THE REGULAR ANNUAL ELECTION AND TO REPORT THE FINAL RESULTS TO THE PRESIDENT. A PREFERENTIAL FORM OF BALLOT SHALL BE COUNTED IN THE FOLLOWING MANNER: THE BALLOT COMMITTEE SHALL COUNT FIRST CHOICE VOTES ONLY. IF NO CANDIDATE RECEIVES A MAJORITY, THE CANDIDATE WITH THE FEWEST VOTES SHALL BE ELIMINATED AND THE SECOND CHOICE ON HIS BALLOTS SHALL BE COUNTED AS FIRST CHOICE FOR THE REMAINING CANDIDATES. THE COMMITTEE SHALL CONTINUE THIS PROCEDURE UNTIL ONE CANDIDATE HAS A MAJORITY."

III. *American Geological Institute.*—

On recommendation of the executive committee, the business committee recommends the ratification of the constitution of the American Geological Institute.

IV. *American Association for the Advancement of Science, Section E.*—

On recommendation of the executive committee, the business committee recommends that the Association affiliate with the American Association for the Advancement of Science, Section E.

V. *Eastern Section.*—

On recommendation of the executive committee, the business committee recommends the establishment of the Eastern Section of the Association, members and associates in good standing, residing in the New York District, to be eligible for membership.

VI. *Code of Ethics.*—

The executive committee recommends and the business committee has approved the following changes in the constitution and by-laws:

1. Add to the constitution, Article III, two new sections to read as follows:

"SECTION 7. EACH MEMBER AND ASSOCIATE SHALL BE GUIDED BY THE HIGHEST STANDARDS OF BUSINESS ETHICS, PERSONAL HONOR, AND PROFESSIONAL CONDUCT.

"SECTION 8. ANY MEMBER OR ASSOCIATE WHO, AFTER DUE INVESTIGATION, IS FOUND GUILTY OF VIOLATING ANY OF THE STANDARDS OF CONDUCT PRESCRIBED IN SECTION 7 OF THIS ARTICLE, MAY BE ADMONISHED, SUSPENDED, ALLOWED TO RESIGN, OR DROPPED FROM MEMBERSHIP IN ACCORDANCE WITH THE PROCEDURE PROVIDED IN THE BY-LAWS."

2. Add to the constitution, Article III, Section 4, the following sentence:

"WITH THE NOTICE OF ELECTION SHALL BE INCLUDED A COPY OF THE CONSTITUTION AND BY-LAWS OF THE ASSOCIATION."

3. Change the by-laws, Article II, Section 5, to read as follows:

"SECTION 5. CHARGES OF MISCONDUCT IN VIOLATION OF THE CODE OF ETHICS OF THIS ASSOCIATION SHALL FIRST BE SUBMITTED IN WRITING TO THE PRESIDENT OF THE ASSOCIATION BY A MEMBER IN GOOD STANDING, IN CONFIDENCE, WITH A FULL STATEMENT OF THE EVIDENCE ON WHICH THE CHARGES ARE BASED. IF IN HIS JUDGMENT THEY MERIT FURTHER CONSIDERATION, HE SHALL APPOINT A COMMITTEE TO CONSIST OF THREE PAST-PRESIDENTS OF THE ASSOCIATION, WHICH SHALL EXAMINE INTO THE CHARGES. IF IN THE JUDGMENT OF SAID COMMITTEE, THE FACTS WARRANT, IT SHALL PREPARE AND FILE WITH THE EXECUTIVE COMMITTEE FORMAL CHARGES AGAINST THE ACCUSED MEMBER OR ASSOCIATE. AS SOON AS MAY BE AFTER THE RECEIPT OF SUCH CHARGES THE EXECUTIVE COMMITTEE SHALL FIX A DATE AND PLACE FOR HEARING THEREUPON, AND SHALL GIVE TO THE ACCUSED PERSON NOTICE THEREOF IN WRITING, MAILED TO HIM BY REGISTERED MAIL AT HIS LAST-KNOWN POST-OFFICE ADDRESS NOT LESS THAN THIRTY (30) DAYS BEFORE SAID DATE, ACCOMPANIED BY A COPY OF THE CHARGES, AND A COPY OF THIS ARTICLE.

4. Add to the by-laws, Article II, four new sections to read as follows:

"SECTION 6. ON THE DAY FIXED FOR THE HEARING, THE ACCUSED PERSON MAY APPEAR BEFORE THE EXECUTIVE COMMITTEE, EITHER IN PERSON OR BY AN ACCREDITED REPRESENTATIVE; HEAR ANY WITNESSES WHO MAY BE CALLED IN SUPPORT OF THE CHARGES; AND, AT HIS OPTION, CROSS-EXAMINE THE SAME, AND HEAR ANY DOCUMENTARY EVIDENCE, INCLUDING A STATEMENT FROM HIMSELF IN WRITING. AT HIS OPTION, HE MAY BY LETTER WAIVE PERSONAL HEARING, AND REQUEST THE EXECUTIVE COMMITTEE TO ADJUDGE THE MATTER ON THE BASIS OF A WRITTEN STATEMENT OF HIS DEFENSE, MAILED TO THE COMMITTEE BEFORE THE DATE SET FOR THE HEARING. AFTER THE CONCLUSION OF THE HEARING, OR STUDY OF WRITTEN DEFENSE SUBMITTED IN LIEU OF A PERSONAL HEARING, THE EXECUTIVE COMMITTEE SHALL CONSIDER AND VOTE TO APPROVE OR DISAPPROVE THE CHARGES. IF THE EXECUTIVE COMMITTEE SHALL, BY UNANIMOUS VOTE, DECLARE THE CHARGES SUSTAINED, IT MAY SUSPEND THE ACCUSED PERSON FROM MEMBERSHIP FOR A STATED PERIOD, ADMONISH HIM, ALLOW HIM TO RESIGN, OR EXPEL HIM. FAILURE OF THE ACCUSED PERSON TO APPEAR EITHER IN PERSON OR BY AN ACCREDITED REPRESENTATIVE SHALL NOT PREVENT THE EXECUTIVE COMMITTEE FROM PROCEEDING WITH THE TRIAL.

"SECTION 7. IF THE ACCUSED PERSON SHALL NOT APPEAR AT THE HEARING NOR WAIVE HIS RIGHT THERETO, AND SHALL WITHIN THREE MONTHS AFTER THE DATE SET FOR THE HEARING FILE WITH THE EXECUTIVE COMMITTEE AN AFFIDAVIT STATING THAT HE HAD NOT RECEIVED NOTICE OF THE CHARGES AGAINST HIM IN TIME TO ENABLE HIM TO PRESENT HIS DEFENSE, THE EXECUTIVE COMMITTEE SHALL FIX A DATE AND PLACE FOR A HEARING NOT LESS THAN THIRTY DAYS NOR MORE THAN THREE MONTHS FROM THE RECEIPT OF SUCH AFFIDAVIT, AND SHALL IMMEDIATELY NOTIFY THE ACCUSED PERSON BY REGISTERED MAIL OF SUCH DATE AND PLACE. UPON THE REHEARING, THE PROCEEDINGS SHALL BE GOVERNED BY THE PROVISIONS OF SECTION 6 OF THIS ARTICLE.

"SECTION 8. RESIGNATION OF THE ACCUSED PERSON FROM MEMBERSHIP IN THE ASSOCIATION, AT ANY STAGE OF THE FOREGOING PRESCRIBED PROCEEDINGS, SHALL AUTOMATICALLY TERMINATE THE PROCEEDINGS.

"SECTION 9. THE DECISION OF THE EXECUTIVE COMMITTEE IN ALL MATTERS PERTAINING TO THE INTERPRETATION AND EXECUTION OF THE PROVISIONS OF SECTION 5, 6, AND 7 OF THIS ARTICLE SHALL BE FINAL."

5. The executive committee recommends and the business committee has approved that the present code of ethics of the Association be abolished if and when the two constitutional amendments, Sections 7 and 8 of Article III, are adopted by the membership.

6. The executive committee recommends and the business committee has approved that the first sentence of Section 5, Article II, of the by-laws as above amended be provisionally amended to read:

"Charges of misconduct in violation of SECTION 7 OF ARTICLE III OF THE CONSTITUTION shall first be submitted in writing to the president of the Association by a member in good standing, in confidence, with a full statement of the evidence upon which the charges are based," such amendment to be made a part of the by-laws only in the event that the two constitutional amendments, Section 7 and 8 of Article III, are adopted.

VII. *Reports of Committees.*—

The business committee recommends that the reports of the standing and special committees which were read and approved in the business committee meeting be approved and published in the *Bulletin*.

ROBERT W. CLARK, *chairman*
EDWARD A. KOESTER, *secretary*

EXHIBIT II. REPORT OF PRESIDENT
(Year Ending April 4, 1946)

It is with a deep sense of appreciation and gratitude to those who have been members of our armed forces and of special war projects that we reassemble in annual meeting under peace-time conditions. Nearly one-fifth of our membership set aside personal safety, economic gain, and comfortable living for our common defense in World War II. We are proud of their record and conscious of the fact that many of our members brought to bear great technical skill and inventiveness, which they had developed as petroleum geologists, engineers, and geophysicists. We pay special homage to those who sacrificed all in this great cause.

During the war years the Association's executive and national service committees have done their utmost for the war effort. It is impossible to over-emphasize how great a contribution this organization in its 30 years existence has made to national security and well-being through the advancement of the science of petroleum geology, the application of which led to the discovery of the enormous quantities of oil needed by this nation and allies to overwhelm the aggressor nations in a world-wide conflict which became a Gargantuan oil-consuming contest of mechanized warfare. The high efficiency of our petroleum industry was of paramount importance to the early termination of this holocaust and to the success of our arms.

We now turn from this national crisis in which individual members and the Association rendered such valuable service to our War and Navy Departments to more normal application of our science to matters of special interest to the Departments of the Interior, Commerce, and State; and we might add, to the Treasury Department. The national welfare is highly dependent on the efficient development and proper conservation of our national resources; the maintenance of a strong domestic oil industry and an adequate supply of fuels for this industrialized nation; and for constructive international relations, which are furthered by the work of our members residing in more than 40 countries.

The full magnitude of the Association's activities can not be readily appreciated until one has had the privilege of serving on the executive committee. During the past year each member of the committee has carried his full share of work, and with but two necessary absences has attended the committee's seven meetings, totaling 16 days. Association affairs for the year are reviewed in this report which embodies both a résumé of the executive and other committee activities and my observations regarding the state of the Association. To have served as president of this organization is a unique privilege for which I am truly grateful.

The executive committee acknowledges with thanks the helpful counsel received from many members as well as from our able and experienced business manager, J. P. D. Hull. The increasing volume of business was handled with facility by him with the help of a very capable and efficient headquarters staff. This marks his twentieth year of faithful service to the Association.

The secretary-treasurer's report will reveal a year of marked progress in membership growth and increased financial resources. In spite of difficulties imposed by the war, the *Bulletin* has maintained its high standard as to quality and number of technical papers, as will be discussed in greater detail by the editor.

The Association's scientific accomplishments must come primarily from the many contributors to our programs and publications, the work of the editor and associate editors, and the several standing and special committees.

During the past year the research and national service committees were given special emphasis. The achievements of these committees should have far-reaching results.

The standing committees for publication, medal award, and statistics of exploratory

drilling have rendered splendid service. The other standing committees deserve much credit for things accomplished under difficult conditions.

The special committee on method of election of officers has made an exhaustive report based on questionnaire returns. The distinguished lecture committee has continued its very important service in spite of great transportation difficulties. It is now recommended that the distinguished lecture committee be made a standing committee. Issues of the *Bulletin* have carried a number of reports by these various committees outlining their plans and the progress of their work.

New undertakings for the year include a special committee for the preparation of *Boy Scout literature*, as suggested by A. C. Bace, and a *directory* of publishers and distributors *of geological information in North America*. J. V. Howell and A. I. Levorsen proposed and are assembling this directory which the Association will publish at an early date.

Cooperation with other geological and scientific organizations is contemplated in the appointment of Ronald K. DeFord as the Association's representative on a joint committee for the development of a *rock color chart*. To lend its weight to the advancement of science in general the executive committee has recommended that the Association affiliate with *Section E* of the *American Association for the Advancement of Science*. A third cooperative step, similarly recommended, is the formal ratification of the constitution of the proposed *American Geological Institute*. This recommendation follows further study of the needs and plans of such an organization, a special duty assigned to the executive committee at the last annual meeting. A conference held last October in Washington, at the invitation of the Geological Society of America and the Division of Geology and Geography of the National Research Council, was attended by representatives of the principal nine national geological organizations, two geophysical organizations, the American Association for the Advancement of Science, and the Canadian Institute of Mining and Metallurgy. Ira H. Cram and M. Gordon Gulley represented the Association. The 185-page transcript records a very thorough discussion which finally led to the appointment of committees to prepare (1) a statement of needs for such an institute and (2) a statement reviewing the history and organization of the proposed institute. It will be recalled that a constitution for the proposed American Geological Institute was published with discussion by A. R. Denison in the February, 1945, issue of the *Bulletin*.

Representatives were appointed to attend a *conference on geological education* held April 3rd at this convention. The conference was arranged by Professor Chester R. Longwell, chairman of the committee on geological training, Division of Geology and Geography, National Research Council. Association representatives, A. I. Levorsen, chairman, will submit their report and recommendations to the executive committee.

The executive committee endeavored to perfect plans for *special volumes* on (1) the oil fields of Venezuela, (2) the Permian of western United States, (3) another volume on the structure of American oil fields, to be dedicated to the memory of Alexander Watts McCoy. The editors are Hollis D. Hedberg, R. K. DeFord, and J. V. Howell. A new volume on the oil fields of the Gulf Coast is also under consideration.

Review of petroleum geology in 1945 is being prepared as a continuation of a joint undertaking of the Association's research committee and the Colorado School of Mines, to be published as an issue of the *Mines Quarterly*.

The Association's *Comprehensive Index* is nearing completion. Reprinting of *Volumes I* and *II, Structure of Typical American Oil Fields*, has been ordered. To meet potential demands, as indicated by post-card inquiry, 1,000 copies of each volume will be printed at the earliest possible date by offset printing method, which is expected to permit sale at somewhat less than original prices for these volumes. The executive committee also directed that available copies of the *Bulletin* missed by any member or associate whose dues were waived during his period of service in the armed forces, be made available to

him at 35¢ per copy upon resumption of his payment of dues, or within twelve months thereafter.

The executive committee recommended the adoption, after certain changes, of the report of the committee on *code of ethics*, as published in the January, 1945, issue of the *Bulletin*.

Proposed amendments to the constitution and by-laws as suggested or recommended by the special committee on *method of election of officers*, set out in committee reports published in the May, 1945, and January, 1946, issues of the *Bulletin*, were declared by the executive committee to be legally phrased. Rejection of the first report and consideration of the proposed amendments in the second report were recommended by the executive committee.

Petition for the establishment of the Eastern Section of the American Association of Petroleum Geologists, signed by Gail F. Moulton, Ben F. Hake, L. G. Weeks, and F. A. Bush, dated January 31, 1946, was approved March 30, 1946, by the executive committee as to form, constitution, and by-laws and favorable action by the Association recommended.

The executive committee also recommended and arranged necessary preliminary steps for amendment of Article II of the Association's *Certificate of Incorporation* at a special meeting of the Association, 3:30 P.M., April 4, 1946.

Professor William Harvey Emmons and Professor Elias Howard Sellards were elected to *honorary membership*. The executive committee approved recommendation of the medal award committee that the president's award of $100 in cash be granted to Horace Gardiner Richards, for his article entitled, "Subsurface Stratigraphy of Atlantic Coastal Plain between New Jersey and Georgia," published in the July, 1945, issue of the *Bulletin*.

It is difficult to over-estimate the mutual advantages derived from cooperation between the Association and its two sections, 26 affiliated societies, and Division of Paleontology and Mineralogy. The president discussed Association affairs at 26 meetings of petroleum geologists, besides many conferences with small groups, during the year. The helpfulness and cordiality of these meetings increases the feeling of regret that lack of time prevented visits to six of our affiliated societies. Meetings and conferences were held in 30 different cities and required 30,000 miles of travel.

The deep interest of our membership in the Association and in the progress of our science was everywhere most evident. It was noted, however, that a wide difference of opinion exists regarding the proper role of the Association in research. This is not a new question, but is one which needs re-examination from time to time as the Association grows in membership and resources and as new conditions arise. Our by-laws define the purpose of the research committee to be "the advancement of research, particularly within the field of petroleum." It can be argued that as Article II of the constitution now stands, our primary object "to promote the science of geology, especially as it relates to petroleum and natural gas" is limited in the field of research by the specific wording which follows, "to foster the *spirit* of scientific research amongst its members." Recent executive and research committees have sensed the necessity of the development of a broad, energetic research program by which the most urgent needs of our science may be determined and projects to meet these needs planned in as complete detail as possible. This places our main interest in background and applied research where, as shown by progress reports of the research committee, innumerable problems exist. Many of the proposed projects are suitable for attack by individuals, others by affiliated societies, State and Federal surveys, educational and research institutions. This Association program should not invade the private research work of industrial laboratories, nor should it be impeded by the thought that one or more industrial laboratories is or may sometime be engaged in studying the same problem. The broad Association objectives and general needs should take precedence.

However, our research work should be of widespread interest, and, of course, stop short of applying such studies to the merits or value of a specific property or locality, this being the normal function of industry under our free enterprise system.

As in the past, moderate use of Association funds for the completion of promising research projects may be desirable, but under present circumstances and to capitalize fully on our greatly expanded research program, maximum returns appear likely not so much through financing research as from use of a portion of our income or surplus or both for the exhaustive planning and attractive presentation of major research projects. Necessary funds for these purposes should be made a certainty to give assurance to our research committee of adequate and continuous support. There is no reason to doubt that research projects selected after surveying the field, designed by specialists and endorsed by the Association committees, will receive the full cooperation of our membership and the financial support from other sources where needed.

The present and recent executive committees have favored the employment of an assistant business manager, chiefly because of increased work at headquarters office, but also to foster the continuity of the work of our various committees and more cooperation between the Association and its affiliated organizations.

It is surprising to note that the Association membership and general fund surplus have doubled during the past ten years, also that the past year showed the largest gain in membership for any year.

There is evident need of constant study and planning of Association policy so that our future may be charted more fully and our course oriented toward maximum service to our science, our industry, and our membership.

M. G. CHENEY, *president*

EXHIBIT III. REPORT OF SECRETARY-TREASURER
(Year ending March 1, 1946)

We have continued to grow during the past year. Membership established another new high on March 1, 1946, when 4,676 members and associates were shown on our rolls. This represents a net increase over last year of 350, the greatest increase in any one year in our history. It is the ninth consecutive year in which a new high in membership has been established. One hundred sixty-one applications for membership and reinstatement are being investigated at present.

We are pleased to welcome those members returning from the armed forces. Many of them who had taken advantage of the ruling in the by-laws which allows them to retain membership without the payment of dues have resumed dues payment and have otherwise again become active members of the Association in the true sense of the word.

Our membership is divided into 11 honorary members, 3,587 active members, 11 life members, and 1,067 associates. Over 90 per cent of our members are in good standing.

Our 4,253 domestic members reside in the District of Columbia and 44 states of the Union. Of 423 members located in 42 foreign countries, 107 are in Venezuela, 76 in Canada, and 68 in Colombia.

While we have made gains, we have also suffered losses. We mourn the passing of 26 members, 6 of whom were killed in line of duty in military service. They are as follows.

MEMBERS AND ASSOCIATES DECEASED

From March 1, 1945

Honorary— Goodrich, Harold B., April 25, 1945

Active— Anderson, Frank M., September 24, 1945
Bravinder, Kenneth M., January 22, 1946
*Baldwin, E. B., January, 1945
Brown, Harry J., April 7, 1945

Burger, Robert W., September 25, 1945
Clark, Bruce L., September 23, 1945
Crider, Albert F., September 25, 1945
*Eberhardt, Adolph T., July 5, 1945
Fuellhart, Donald E., October 23, 1945
Galliher, E. Wayne, April 29, 1945
*Golden, John M., December 8, 1945
Heaton, Adrian H., March, 1945
Henderson, Charles W., January 26, 1945
Henning, John L., May 21, 1945
Hesse, Curtis J., May 12, 1945
Hogan, Dana, December 14, 1945
Holden, Roy J., December 17, 1945
Kirk, Charles T., June 1, 1945
Milton, William B., Jr., November, 1945
*Orr, Mark L., April 13, 1945
Schillhan, E. O., August 3, 1945
Schilling, Karl H., July 17, 1945
Shearer, Harold K., January 24, 1946

Associate—*Breed, Edgar R., July 5, 1945
*Conway, William Palen, Jr., February, 1944

* Died in line of duty in military service.

Tables I, II, and III give detailed data concerning membership and geographic distribution thereof.

Finances.—In order to simplify the data presented in the annual audit of Arthur Young and Company, which was published in the March, 1946, *Bulletin*, the following tabulations have been prepared.

STATEMENT OF INCOME AND EXPENSE, 1945
(December 31, 1945)

Income		
Dues	$41,766.00	
Interest and Dividends	3,870.40	
Income from Publications	43,693.79	
Miscellaneous Income	1,398.25	
	$90,728.44	$90,728.44
Expenses		
General Expenses	$22,016.85	
Publication Expense	44,400.56	
Convention Expense	241.77	
Research Expenses	1,018.49	
	$67,724.67	$67,724.67
Net Income		$23,003.77

I wish to point out that, as shown in Table IV, which with the other tables accompanying this report will be published in the *Bulletin*, income from advertising last year was over $21,000 compared with $16,000 in 1944 and less than $9,000 in 1943. Income from subscriptions, sale of back numbers, and special publications was greater than usual. I mention these facts to refute the impression that has grown up among some members that our present apparently prosperous condition is due to an excess of income from dues over normal operating expenses and publication costs. On the contrary we have been able to show a net income each year for several years only because of a great increase in advertising income and an excess of income from publications over publication expense. The Association has issued no new publications since 1942 except the *Tectonic Map of the United States*. Within the next two years we will have the expense of publishing a Permian volume, a Venezuelan volume, the Alex McCoy Memorial volume (another volume on the structure

of American oil fields), a Comprehensive Index and the re-publication of Volumes I and II, *Structure of Typical American Oil Fields*. These will draw heavily upon our Publication Fund reserves.

An analysis of the Association income dollar shows that for each dollar we took in last year, 46 cents came from dues, 4 cents from interest on investments, 24 cents from advertising, 24 cents from sale of publications, and two cents from miscellaneous sources.

We spent this income dollar as follows: 39 cents was spent on the preparation and distribution of the *Bulletin*, 26 cents on general expenses, 8 cents is charged to depreciation of inventory, one cent was given to the Society of Economic Paleontologists and Mineralogists, one cent was spent on research, and 25 cents went to surplus.

With this surplus we are building up a reserve of cash and investments which will not only tide us over the lean years of some future business depression but which, in my opinion will allow us better to serve the membership through a well planned program of research and publication.

Assets.—During the calendar year the Association has invested $19,900 in U. S. Government bonds. Our total assets at the first of the year were at an all-time high of $208,469.11. This was divided as follows.

	Cost Value
U. S. Government Bonds	$ 69,400.00
Industrial Bonds	11,080.35
Preferred Stocks	8,858.99
Common Stocks	32,218.02
Savings Account	4,967.78
Total Investments	$126,525.14
Cash and Inventory	$ 81,943.97
Total Assets	$208,469.11

The present executive committee early in its term of office authorized the investment of a considerable part of our uninvested cash but on the advice of our investment counsel these purchases were not consummated until recently, so they do not show as investments in the foregoing tabulation.

The rate of return on the investments of the Association in 1945 was 3.2 per cent.

1946 Budget.—Table X gives a tabulation of the estimated budget for 1946. It provides for an income of $84,000 and expenditures of $70,320. I wish to point out here that publication expenses may be much higher than shown in the budget if material and paper are available for special publications. This item may run into several thousand dollars.

Executive committee meetings.—During the year meetings of the executive committee were held as follows.

Tulsa	March 28, 1945
Fort Worth	May 15–16, 1945
Chicago	July 8–9, 1945
Tulsa	September 20–22, 1945
Wichita	November 16–18, 1945
Chicago	Feb. 28–March 2, 1946
Chicago	March 30–31, 1946

Acknowledgments.—During 1946, J. P. D. Hull will complete twenty years of faithful service as the business manager of your Association. I seriously doubt that anyone except an officer of this Association can realize fully just how much each of us owes to him for the smooth running of our organization. He is more than a business manager; he is a member of our profession who has the interests of it at heart at all times; his door is open to the chief geologist and freshly graduated novice alike. To many people, Joe Hull personifies

the American Association of Petroleum Geologists. To him, his capable staff, the members of the executive committee, and other workers in the Association, I extend my thanks for help, counsel, and consideration.

EDWARD A. KOESTER, *secretary-treasurer*

TABLE I

TOTAL MEMBERSHIP BY YEARS

May 19, 1917	94	March 1, 1932	2,558
February 15, 1918	176	March 1, 1933	2,336
March 15, 1919	348	March 1, 1934	2,043
March 18, 1920	543	March 1, 1935	1,973
March 15, 1921	621	March 1, 1936	2,169
March 8, 1922	767	March 1, 1937	2,331
March 20, 1923	901	March 1, 1938	2,646
March 20, 1924	1,080	March 1, 1939	2,951
March 21, 1925	1,253	March 1, 1940	3,240
March 1, 1926	1,504	March 1, 1941	3,474
March 1, 1927	1,670	March 1, 1942	3,717
March 1, 1928	1,952	March 1, 1943	3,923
March 1, 1929	2,126	March 1, 1944	4,109
March 1, 1930	2,292	March 1, 1945	4,326
March 1, 1931	2,562	March 1, 1946	4,676

TABLE II

COMPARATIVE DATA OF MEMBERSHIP

	March 1, 1945		*March 1, 1946*	
Number of honorary members	12		11	
Number of life members	9		11	
Number of members	3,298		3,587	
Number of associates	1,007		1,067	
Total number of members and associates		4,326		4,676
Net increase in membership		217		350
Total new members and associates	250		331	
Total reinstatements	53		76	
Total new members and reinstatements		303		407
Applicants elected, dues unpaid	36		14	
Applicants approved for publication	49		39	
Recent applications	50		100	
Total applications on hand		135		153
Applicants for reinstatement elected, dues unpaid	2		3	
Recent applications for reinstatement	2		5	
Total applications for reinstatement on hand		4		8
Applicants for transfer approved for publication	18		20	
Recent applications for transfer on hand	14		29	
Total applications for transfer on hand		32		49
Number of members and associates resigned	11		13	
Number of members and associates dropped	55		20	
Number of members and associates died	20		24	
Total loss in membership		86		57
Total gain in membership		303		407
Number of members and associates in arrears, previous years	58		50	
Members in arrears, current year	309		318	
Associates in arrears, current year	134		109	
Total number members and associates in arrears, current year		443		427
Total number members and associates in good standing		3,825		4,199

TABLE III

GEOGRAPHIC DISTRIBUTION OF MEMBERS

March 1, 1946

Alabama	18	Louisiana	238	Ohio	28
Arizona	6	Maryland	11	Oklahoma	625
Arkansas	22	Massachusetts	21	Oregon	8
California	554	Michigan	48	Pennsylvania	90
Colorado	103	Minnesota	8	Rhode Island	1
Connecticut	7	Mississippi	108	South Carolina	3
Delaware	2	Missouri	29	South Dakota	8
Dist. of Columbia	71	Montana	25	Tennessee	10
Florida	38	Nebraska	8	Texas	1,453
Georgia	4	New Hampshire	1	Utah	11
Illinois	108	New Jersey	14	Virginia	6
Indiana	50	New Mexico	37	Washington	13
Iowa	11	New York	145	West Virginia	17
Kansas	177	North Carolina	4	Wisconsin	10
Kentucky	22	North Dakota	1	Wyoming	79

Total members in United States 4,253

Alaska	1	Dominican Republic	1	Nova Scotia	1
Alberta	54	Ecuador	13	Ontario	12
Angola	1	Egypt	9	Palestine	1
Argentina	14	England	17	Panama	1
Australia	9	France	3	Paraguay	1
Bahamas	2	Germany	1	Persian Gulf	3
Barbados	1	Gold Coast	1	Peru	14
Belgian Congo	1	Haiti	1	Quebec	1
Bolivia	3	Honduras	1	Saskatchewan	2
Brazil	5	India	3	Switzerland	6
British Columbia	2	Iraq	2	Syria	1
British Guiana	1	Mexico	14	Tasmania	1
Chile	5	Netherlands	3	Trinidad	14
Colombia	68	New Brunswick	2	Turkey	3
Cuba	7	New Zealand	5	Uruguay	1
Denmark	1	Nicaragua	1	Venezuela	107
		Northwest Territory	2		

Total members in foreign countries 423
Grand total 4,676

TABLE IV

COMPARISON OF ACCRUED INCOME BY CALENDAR YEARS

	1943	1944	1945
Dues			
Members	$30,320.00	$31,540.00	$34,900.00
Associates	6,096.00	6,452.00	6,866.00
Total	$36,416.00	$37,992.00	$41,766.00
Bulletin			
Subscriptions	$ 4,125.10	$ 5,160.46	$ 5,774.52
Advertising	8,728.54	16,507.39	21,533.09
Total	$12,853.64	$21,667.85	$27,307.61
Back Numbers, etc.			
Bound Volumes of Bulletin	$ 2,959.20	$ 3,389.00	$ 3,479.50
Back Numbers of Bulletin	1,448.46	2,160.68	2,507.36
Other Publications	117.16	274.86	595.44
Total	$ 4,424.82	$ 5,824.54	$ 6,582.30
Special Publications			
Geology of Natural Gas*	$ 592.62	$ 616.00	$ 487.20
Geology of Tampico Region*	257.10	228.65	212.90
Gulf Coast Oil Fields*	343.63	441.80	392.60
Map of Southern California*	30.85	26.80	34.50
Miocene Stratigraphy of California*	206.50	255.50	233.00
Recent Marine Sediments*	63.00	—	4.00
Stratigraphic Type Oil Fields*	1,296.01	1,205.12	1,376.95
Source Beds of Petroleum*	692.97	692.20	685.05
Possible Future Oil Provinces	328.24	426.77	607.78
Origin of Oil	120.90	25.00	13.90
Permian of West Texas and SE. N. Mex.	445.70	108.60	—
Petroleum Discovery Methods	340.00	253.80	98.70
Sedimentation	293.50	8.00	3.00
Tectonic Map of United States	—	765.50	5,635.90
Total	$ 5,011.02	$ 5,053.75	$ 9,785.48
Other Income			
Delinquent Dues Charged Off	$ 360.00	$ 708.00	$ 1,104.65
Interest, General Fund	1,793.68	3,025.25	2,818.78
Interest, Publication Fund	518.72	600.77	757.76
Interest, Research Fund	60.15	59.56	61.36
Interest, Powers Medal Fund	—	168.34	232.50
Profit, sale of Investments, General	—	4.82	1.50
Profit, sale of Investments, Publication	—	—	41.25
Miscellaneous	155.88	196.11	188.35
Sale of Library	17.50	6.00	16.00
Members Reinstated	49.75	42.23	46.50
Adjustments of stated value of Investments to lower of Cost or Market	2,760.39	4,421.83	—
Regional Cross Sections	43.45	30.80	18.40
Inventory Increase	—	3,168.68	—
Donations, Powers Medal Fund	5,296.50	4,818.50	—
Total	$69,761.50	$87,789.02	$90,728.44

* Income of Publication Fund.

TABLE V

COMPARISON OF ACCRUED EXPENSES BY YEARS

General and Administrative Expenses	*1943*	*1944*	*1945*
Salaries—Manager	$ 4,250.00	$ 3,750.00	$ 4,000.00
Clerical	5,353.45	6,400.80	6,852.94
Payroll Taxes	422.10	469.81	538.13
Rent	1,674.00	1,782.00	2,037.00
Telephone and Telegraph	304.09	306.72	379.05
Postage	2,043.95	2,014.31	2,383.88
Office Supplies and Expenses	564.22	459.64	1,146.87
Printing and Stationery	673.04	624.99	712.14
Audit Expense	300.00	300.00	300.00
Insurance	239.29	164.11	295.32
Convention Expense (Net)	350.41	811.85	241.77
Freight and Express	270.39	213.59	503.60
Bad Debts	1,002.23	346.07	351.84
Miscellaneous	227.08	287.94	449.35
Depreciation—Furniture and Fixtures	111.33	—	—
Investment Counsel	400.00	400.00	400.00
Traveling Expenses	205.74	270.88	274.24
Research Projects and Expense	957.75	763.75	1,018.49
Donation—Soc. of Econ. Paleon. and Mineralogists	1,500.00	—	1,000.00
Distinguished Lecture Committee	500.00	—	—
National Service Committee	364.62	190.40	11.57
American Geol. Institute	327.50	59.36	22.44
Powers Medal Expense	—	685.77	305.48
President's Award	—	—	100.00
Total	$22,059.19	$20,301.99	$23,324.11
Publication Expenses			
Salaries—Manager	$ 3,750.00	$ 3,750.00	$ 4,000.00
Editorial	3,980.50	4,251.29	4,317.17
Printing Bulletin	16,328.20	19,195.74	22,505.48
Engravings	1,932.69	2,113.05	2,016.53
Separates	161.88	186.33	305.46
Stencils and Mailing	350.67	359.22	341.15
Binding Bulletins	623.05	597.69	674.48
Postage and Express (Bulletins)	765.36	852.69	929.83
Copyright Fees	24.00	24.00	24.00
Freight, Express, Postage (Other Publications)	92.82	102.92	87.56
Miscellaneous	50.38	241.22	41.39
Special Publications	637.76	6,012.55	1,686.75
Special Publication Inventory Decrease	5,546.08	—	7,451.92
Regional Cross Sections	44.53	28.57	18.84
Total	$34,287.92	$37,715.27	$44,400.26
Total Expense	$56,347.11	$58,017.26	$67,724.57

TABLE VI

COMPARISON OF NET INCOME BY YEARS

	1943	*1944*	*1945*
Accrued Income	$69,761.50	$87,789.02	$90,728.44
Expenses			
General and Administrative	22,059.19	20,301.99	23,324.11
Publication	34,287.92	37,715.27	44,400.56
Total	$56,347.11	$58,017.26	$67,724.67
Excess Income over Expenses	$13,414.39	$29,771.76	$23,003.77

TABLE VII

INVESTMENTS

	Cost	Market Value End of Year
1943 Values		
General Fund	$ 63,625.03	$ 60,282.23
Publication Fund	16,622.40	15,544.62
Research Fund	2,545.85	2,544.60
Total	$ 82,793.28	$ 78,371.45
1944 Values		
General Fund	$ 72,346.42	$ 71,550.90
Publication Fund	21,456.99	20,959.25
Research Fund	2,606.56	2,724.06
Powers Medal Fund	9,300.00	9,300.00
Life Membership Fund	1,600.00	1,600.00
Total	$107,309.97	$106,134.21
1945 Values		
General Fund	$ 82,552.18	$ 86,503.70
Publication Fund	29,605.09	31,090.21
Research Fund	2,667.87	2,780.37
Powers Medal Fund	9,300.00	9,050.40
Life Membership Fund	2,400.00	2,340.80
Total	$126,525.14	$131,765.48

TABLE VIII

COMPARISON OF COST OF BULLETIN

	1943	*1944*	*1945*
Total Expenses	$27,958.98	$31,377.35	$35,152.39
Monthly Edition	5,000	5,300	5,900
Total Copies Printed	60,000	63,000	70,200
Total Pages Printed, including Covers	2,118	2,354	2,448
Total Pages of Text	1,674	1,810	1,819
Total Cost per Copy	$ 0.465	$ 0.49	$ 0.50

TABLE IX

(Section 1)

SPECIAL PUBLICATIONS

	Geology Natural Gas (1935)	*Geology Tampico Region (1936)*	*Gulf Coast Oil Fields (1936)*	*Tectonic Map of California (1936)*	*Total*
Inventory					
Dec. 31, 1944	$ 468.00	$1,209.12	$ 319.41	$ 30.40	$ 2,026.93
Dec. 31, 1945	84.00	1,012.18	86.00	24.72	1,206.90
Sales	487.20	212.90	392.60	34.50	1,127.20
Total Edition	2,500	1,575	2,510	940	
Copies on Hand					
Dec. 31, 1944	117	528	182	380	
Dec. 31, 1945	21	442	49	309	
Number of Pages	1,227	280	1,070	—	
Cost (inventory) per Copy	$ 4.00	$ 2.29	$ 1.755	$ 0.08	
Selling Price					
Members and Associates	4.50	3.50	3.00	0.50	
Non-Members	6.00	4.50	4.00	0.50	

TABLE IX

(Section 2)

SPECIAL PUBLICATIONS

	Miocene Stratigraphy of California (*1938*)	*Stratigraphic Type Oil Fields* (*1942*)	*Source Beds of Petroleum* (*1942*)	*Tectonic Map of U.S.* (*1944*)	*Total*
Inventory					
Dec. 31, 1944	$1,757.25	$2,457.96	$1,102.50	$5,697.54	$11,015.25
Dec. 31, 1945	1,571.63	1,467.44	561.05	1,875.49	5,475.61
Sales	233.00	1,376.95	685.05	5,635.90	7,930.90
Total Edition	1,530	2,526	1,539	5,000	
Copies on Hand					
Dec. 31, 1944	710	871	450	4,569	
Dec. 31, 1945	635	520	229	1,504	
Number of Pages	450	902	566	—	
Cost (inventory) per Copy	$ 2.475	$ 2.822	$ 2.45	$ 1.247	
Selling Price					
Members and Associates	4.50	4.50	3.50	1.75	
Non-Members	5.00	5.50	4.50	1.75	

TABLE IX

(Section 3)

SPECIAL PUBLICATIONS

	Origin of Oil (*1941*)	*Petroleum Discovery Methods* (*1942*)	*Sedimentation* (*1943*)	*Possible Future Oil Provinces* (*1941*)	*Total*
Inventory					
Dec. 31, 1944	$ 56.24	$ 77.26	$ 26.69	$ 246.23	$ 406.42
Dec. 31, 1945	28.93	17.40	7.85	91.08	145.26
Sales	13.90	98.70	3.00	607.78	723.38
Total Edition	905	1,500	1,208	3,052	
Copies on Hand					
Dec. 31, 1944	109	111	85	611	
Dec. 31, 1945	58	25	25	226	
Number of Pages	81	164	68	154	
Cost (inventory) per Copy	$ 0.516	$ 0.696	$ 0.314	$ 0.403	
Selling Price					
Members and Associates	1.00	1.00	0.50	1.00	
Non-Members	1.00	1.00	1.50	1.50	

TABLE X
BUDGET

	1945	1946 Est.
REVENUE		
Dues		
Members	$34,540.00	$36,000.00
Associates	6,866.00	7,000.00
Reinstatements and Delinquents	1,151.15	750.00
	$42,557.15	$43,750.00
Bulletin		
Subscriptions	$ 5,774.52	$ 6,000.00
Advertising	21,533.09	20,000.00
Bound Volumes	3,479.50	3,000.00
Back Numbers	2,507.36	2,000.00
	$33,294.47	$31,000.00
Other Publications	595.44	500.00
	$33,889.91	$31,500.00
Special Publications		
Geology of Natural Gas	$ 487.20	$ 100.00
Geology of Tampico Region	212.90	200.00
Gulf Coast Oil Fields	392.60	100.00
Map of Southern California	34.50	25.00
Miocene of California	233.00	200.00
Recent Marine Sediments	4.00	10.00
West Texas Sections	18.40	15.00
Stratigraphic Type Oil Fields	1,376.95	1,200.00
Source Beds of Petroleum	685.05	500.00
Possible Oil Provinces	607.78	300.00
Origin of Oil	13.90	—
Discovery Methods	98.70	—
Sedimentation	3.00	—
Tectonic Map of U. S.	5,635.90	2,500.00
	$ 9,803.88	$ 5,150.00
Other Income		
Investments	$ 3,913.15	$ 4,400.00
Miscellaneous	204.35	200.00
	$ 4,117.50	$ 4,600.00
TOTAL REVENUE	$90,368.44	$84,000.00
EXPENSE	1945	1946
General and Administrative		
Salaries	$10,852.94	$15,500.00
Payroll Taxes	538.13	775.00
Rent	2,037.00	2,200.00
Telephone and Telegraph	379.05	400.00
Postage	2,383.88	2,400.00
Audit	300.00	300.00
Investment Counsel	400.00	400.00
Insurance	295.32	300.00
Bad Debts	351.84	375.00
Convention (net)	241.77	300.00
Office Supplies	896.24	900.00
Printing and Stationery	712.14	750.00
Freight and Express	335.88	400.00
Miscellaneous	449.35	500.00
Travelling Expenses	274.24	300.00
Research Committee	1,018.49	3,000.00

TABLE X—*Continued*

	1945	*1946 Est.*
Donation to S.E.P.M.	1,000.00	1,000.00
National Service Comm.	11.57	—
Amer. Geol. Institute	22.44	100.00
Powers Medal	305.48	—
President's Award	100.00	100.00
	$23,073.48	$30,000.00
Bulletin Publication		
Salaries	$ 8,317.17	$ 8,500.00
Printing	22,505.48	23,000.00
Engraving	2,016.53	2,500.00
Separates	305.46	350.00
Stencils and Mailing	341.15	400.00
Cloth Binding	674.48	700.00
Postage and Express	929.83	950.00
Miscellaneous	65.39	100.00
	$35,156.49	$36,500.00
Special Publications		
West Texas Sections	$ 18.84	$ 20.00
Tectonic Map of U. S. (Tubes, freight, express)	418.35	200.00
Special Volumes	—	1,500.00
Freight, Express, Postage	87.56	100.00
Comprehensive Index	1,686.75	2,000.00
	$ 2,211.50	$ 3,820.00
TOTAL EXPENSE	$60,441.47	$70,320.00

Exhibit IV. Report of Editor

In spite of the many restrictions placed on all types of civil activities for the past few years the *Bulletin* has come through the War without its size reduced or its quality becoming impaired in any significant way. The scarcely observable failure to maintain the pre-war standard of heavy paper has drawn little adverse comment, and has been no real handicap to scientific achievement.

The Association has been able to publish a full volume of creditable scientific papers of broad general interest. The constant fear under which the editors worked last year that there would not be enough manuscripts to print a *Bulletin* of normal size has plagued them less this year. The current reserve of good papers, while not large, is comfortable, and it has been possible to formulate a more balanced arrangement of subject matter according to numbers.

The pagination of the *Bulletin* shows that 8 more pages were printed in 1945 (1820 pp.) than in 1944. It has been possible, therefore, to maintain quantity production as well as quality. Because the size of the type page has been increased and because authors have been found to prepare the manuscripts, more words have actually been published than in many former years.

The marked decline in the number of papers for the *Bulletin* originating in the programs of the annual meeting extended over the period from 1941 to 1945, and was the cause of considerable concern to the editors. Happily, this important source of many of the *Bulletin's* most significant papers is now restored. Your editor also feels that the President's Award has acted as a definite stimulus to the preparation of good papers during the past 2 years and that its influence will be felt increasingly in the years to come.

You will observe from the secretary's figures that the cost of publishing the *Bulletin*

is again somewhat greater than in previous years. Again, however, the size of the addition has been considerably increased and the number of pages printed in the volume somewhat greater. It appears probable that the cost of succeeding volumes will be even more.

Desirable as it would be to improve the quality of the paper upon which the *Bulletin* is printed, there appears to be little likelihood that this can be done in the near future. The Government restrictions on paper for publications such as the *Bulletin* have been lifted, but the printers report that it is quite impossible to obtain the grade of paper formerly used in anything like the quantity required.

No major change in the policy of the *Bulletin* during the last 2 years has seemed desirable. The editor's report last year called attention to the possible value of the Discussion section and urged that more positive use be made of it. During the year a new set of "Directions to Authors" was prepared and distributed widely. Late in 1945 letters were sent to the associate editors outlining a plan for systematically getting into the *Bulletin* more up-to-date information on oil and gas fields, particularly new discoveries. Response to the letters was favorable, but in the meantime correspondence between Paul Weaver, F. H. Lahee, and C. E. Dobbin has developed a much simpler and more efficient plan for handling the material. It will now be assembled by the authors of the Development Papers for the respective district under the direction of Lynn K. Lee, and with the cooperation and assistance of the committee on statistics of exploratory drilling.

During 1945 your executive committee and editorial staff have continued to consider carefully the many problems of Association publication, and substantial progress has been made.

The *Comprehensive Index* is still in the process of slow but careful preparation. The work must be painstakingly done, and experienced editorial assistance is difficult to obtain. Even should the typewritten copy be ready for the printer late this year, there is still the possibility that lack of materials and services at the printers may make it impossible to distribute the Index before 1947.

A canvass of the membership has been made to determine the advisability of reprinting the long-since exhausted Volumes I and II of *Structure of Typical American Oil Fields*. The response was entirely favorable, and steps are now being taken to make these important volumes again available.

The executive committee, the editorial board, and others interested in the Association's publications have been diligent in pressing work on special publications already proposed and in searching out others to add to the Association's already impressive list. It appears that considerable advancement is being made on a *Permian Volume*, a volume on *Geology of the Oil Fields of Venezuela*, and a third volume on the *Structure of American Oil Fields*. Still other possibilities are receiving serious consideration.

Again your editor would like to express his deep gratitude for the unfailing support of all members of the Association in the important work of publishing the *Bulletin*. All the associate editors and the members of the highly important publications committee are experienced and scholarly men and have performed their voluntary tasks promptly and with distinction; and all have found it a pleasure to work with the Association's efficient and devoted headquarters staff.

GAYLE SCOTT, *editor*

EXHIBIT V. REPORT OF RESOLUTIONS COMMITTEE

Be it resolved, 1, that we, in behalf of the members of the American Association of Petroleum Geologists and associated Societies of Economic Paleontologists and Mineralogists and of Exploration Geophysicists, express our sincere appreciation to the executive committee, which had the sole responsibility of making this, our first post-war convention, an outstanding success.

2. To Monroe G. Cheney, president of our Association, and the officers of the associated societies who, for this annual convention in Chicago, have cooperatively served so successfully in the unusual capacity of program chairmen.

3. To Ira H. Cram of the executive committee for his thought and untiring effort devoted to arrangements for, and success of, the convention.

4. To J. P. D. Hull and his business staff for their efficient planning and management.

5. To the Pure Oil Company for furnishing services that are normally the function of the host society.

6. To Edward C. Dapples, and members of the Department of Geology of Northwestern University, D. Jerome Fisher and members of the Department of Geology of the University of Chicago for providing projection equipment and operating personnel essential to the technical program.

7. To the management and convention staff of the Stevens Hotel and the co-operating hotels of Chicago for their capable housing of our members and guests.

And, *be it further resolved*, that we express our appreciation to S. W. Lowman in particular, and to the research committee in general, for the vast amount of time and constructive thought devoted to the research program which has formed an important part of our convention program.

HAROLD W. HOOTS, *chairman*, FRANK GOUIN, HENRY N. TOLER

EXHIBIT VI. REPORT OF DISTINGUISHED LECTURE COMMITTEE

(1945–46 Season)

The distinguished lecture committee wishes to express its appreciation to the following speakers who have made possible the completion of another successful year.

Charles B. Hunt	U. S. Geological Survey
Chester R. Longwell	Yale University
Bailey Willis	Stanford University
Parke A. Dickey	Quaker State Oil Refining Corporation
Harold W. Scott	University of Illinois
T. S. Oakwood	Pennsylvania State College
W. H. Twenhofel	University of Wisconsin
Horace G. Richards	Philadelphia Academy of Natural Sciences

During the current season 125 lectures were arranged for 35 separate geological groups, compared with 130 lectures for 36 groups during 1944–1945 season; 110 lectures for 27 groups during 1943–1944 season; and 77 lectures for 25 groups during the 1942–1943 season. This year we have had to eliminate many requests for speakers because of travel restrictions.

For the past 12 months we have operated under the most strenuous problems of transportation which to date have been encountered. Congested troop movements during the first part of the season, withdrawal of Pullman service of many lines, the 15-day limit and during part of the year a 5-day limit on Pullman reservations, has necessarily added to the difficulties under which we have labored. Without the very fine cooperation which we have received from the individual geological groups, this committee would not have been able to carry on its work. Due to the restrictions on the sale of Pullman tickets, we have frequently called upon the officers of these groups to purchase rail tickets for us and it is impossible to praise too highly the help which we have received from this source. In addition, on numerous occasions the societies have generously furnished automobile transportation between meeting places, thus eliminating many crowded train rides. During this season the committee has placed eight speakers before the affiliated societies. It has supplied a list of these speakers well in advance of their appearance and in only one case did

a speaker fail to appear as scheduled and that was caused by a 4-hour delay in airline transportation due to unfavorable weather.

Six new groups participated in these lectures for the first time and unaffiliated groups are still asking to be included. Of the thirty-five separate organizations included in these tours twenty-four are affiliated, the others are related geological organizations.

We are now faced with the decision whether or not to expand these tours to accommodate all groups asking to be included. The average speaker has spent thirty days on the road and to ask more time would be an imposition. By excluding any interested and enthusiastic group the Association is losing an opportunity to further the dissemination of geological knowledge under its sponsorship. The committee recommends serious consideration by the executive committee as to whether we should let this activity continue to grow by taking in additional societies and sponsoring more speakers to fill their requests, or to curtail the number of societies to those which are affiliated.

The committee has actively used the $1,000 revolving fund of the Association to take care of its transactions. Due to increased costs of travel, this fund would not have been sufficient, if the local societies had not been so prompt in taking care of their obligations. All societies have paid promptly and the fund is intact.

It is recommended that the fund remain at $1,000 for the coming year.

FRED H. MOORE, *chairman*

EXHIBIT VII. REPORT OF TRUSTEES OF RESEARCH FUND

The Research Fund, created in 1925 through the initiative of W. E. Wrather and augmented by member donations, by transfer of surplus convention funds from the New Orleans meeting in 1938, by resolution of the executive committee in 1939 and by annual income from investment, amounted to $2,727.58 on December 31, 1945. No meetings of the trustees were held during the year but by correspondence approval was given to the executive committee's request that funds in the amount of $300 be made available for partly defraying travelling expenses of members of the research committee which were incurred in making a national survey of the field of petroleum geological research. It was subsequently decided however to meet these expenses from the general fund, so no expenditure was made from the research fund during 1945.

As it now exists the research fund is only moderately useful. It is too pitifully small to merit separate existence; it is too venerable to warrant extinction by transfer to other Association accounts. It therefore seems desirable to this retiring trustee to recommend to the incoming executive committee that one of the urgent Association objectives be declared to be the seeking of suitable ways and means of building up the research fund until it shall be somewhat commensurate with the membership's avowed interest in research in petroleum geology. The present fund, amounting to about 61 cents per member, does not at all reflect the growing research-mindedness made evident in recent Association meetings.

C. L. MOODY, *chairman*

EXHIBIT VIII. REPORT OF REPRESENTATIVES ON COMMISSION ON CLASSIFICATION AND NOMENCLATURE OF ROCK UNITS

The representatives have received during the year no communication whatever from the commission on classification and nomenclature of rock units. It is judged, therefore, that that commission has either been completely inactive, or has had no occasion to call upon the representatives of the A.A.P.G. named to participate in its work.

C. W. TOMLINSON *chairman*

Exhibit IX. Report of National Service Committee

GENERAL STATEMENT

After the Tulsa meeting last year there was considerable delay in selecting a chairman, organization, and program of this committee. After all of these details had been ironed out and approval of them obtained by the executive committee, this committee started to function. A five-point program was adopted as follows.

1. Secure and organize the experience records of returning veterans, particularly those who have seen service in actual battle areas.
2. Keep abreast of changes in Selective Service regulations and be prepared to advise members who seek counsel of us on these matters.
3. Cooperate with other organizations in promoting the teaching and wider use of geology by the Armed Services, including the development of the criteria for military application and curricula for teaching same.
4. Keep informed on legislative and other developments and pronouncements which may have point for the profession.
5. Develop a program of effective assistance to members returning to civilian life to secure employment, where assistance may be proper, and especially assistance to those who on account of physical injuries, may need counsel to adapt themselves to a change of status or other duties in geological work.

A discussion of the foregoing program together with the roster and duties of vice-chairmen and working plan of carrying out these activities, was outlined in brief form in the December *Bulletin*.

We have attempted to carry out this program of objectives. However, most of these are in the progress stage only and can not be considered as completed this year. Several of these activities are overlapping and a regrouping or reallocation may be in order in the event that the work of this committee is continued. A brief progress report on the foregoing objectives follows.

VETERANS' SERVICE RECORDS

The vice-chairman in charge of this phase of our program is K. C. Heald. It was our intention to secure as many service records as possible in order to make an analysis of the use or possible use of geology in the military operations of World War II.

We were especially interested in securing those from the veterans who were in positions such as would enable them to describe and evaluate the actual as well as the possible uses. It is our hope that such an analysis will be of material value in a final program of recommendations for the application of geology to military operations. These experience records have been coming in very slowly and very few in number, so that no report can be given at this time as it would not reflect the necessary amount of information desired. This being the case only a few general remarks can be offered at this time.

Some of these records are outstanding in showing that geological training and experience have been very valuable in the performance of duty and aid in furnishing excellent intelligence information for many types of operations. Many of these records also reflect opinions and judgment of where and how geologists could have been of great help in operations where geological information was not available or used.

Many of these records will also reflect that geologists with an excellent background for Terrain Intelligence were placed in nontechnical positions where their skills in this respect were not needed.

Mr. Heald reports that from such records as received that they furnish excellent support for our belief that there should be a definite place for geologists in various branches of the service and also that geology should be taught to all Army and Navy cadets.

If the Association decides to continue the work of this committee, this analysis when complete could well be one of the best contributions we could make for the improvement of military operations.

SELECTIVE SERVICE

W. B. Heroy, vice-chairman, has assisted us in keeping up with the many changes in this respect. All of this information, together with that furnished from the Office of Scientific Personnel in Bulletins Nos. 26 and 27, has been forwarded to all members of our committee with the request that it be relayed to the affiliated geological societies for the benefit of all concerned.

There have been many changes in Selective Service since our last annual meeting and especially so since V-J Day. For more up-to-date details on this subject and the release of personnel from the services you are referred to the aforementioned Bulletins Nos. 26, 27, and 29, which can be obtained by writing to M. H. Trytten, Director of Office of Scientific Personnel, 2101 Constitution Avenue, Washington 25, D. C.

There was a very strong trend throughout the War in recognizing and making use of all scientific research and accomplishments. Since we have now embarked on an Atomic Age, the nation has become extremely "science-minded" and appropriately so. The geological profession has a definite place in this plan, so that in whatever the future holds for us there should be a conservation of our manpower as geologists to be used in teaching, research, industry, and Armed Forces.

MILITARY APPLICATION OF GEOLOGY

Vice-chairman Charles B. Hunt of the United States Geological Survey is one of the most informed and experienced members for this assignment. The work of the Geological Unit of the Survey in the actual application of geology to military operations in World War II is outstanding. Most of you are familiar with this work as outlined by Mr. Hunt's lecture in his appearance before the affiliated societies of A.A.P.G. The articles published in the *Saturday Evening Post*, March 24, 1945, and *World Petroleum*, April 1, 1945, together with his lectures have done more to enlighten the public about the use of geology in military operations than any amount of publicity on our part. The potentialities of the unit started from scratch, and as time went on, became stronger by leaps and bounds, and the importance to Military Intelligence of many types of geological terrain information became well recognized. It is the opinion of many, should the War have continued, that the geological work would have expanded considerably. Even though the early efforts of members of the national service committee seemed at the time to run up against a stone wall in attempting to interest some branches of the Armed Forces in the application of geology to military operations, at any rate, we have a very strong suspicion that the seeds we planted did bear fruit.

It is unfortunate for the profession as well as military operations that this interest did not appear at an earlier date, so that at least most of our members in the Armed Forces could have utilized their excellent training and experience as geologists (Terrain Specialists)—whether attached to headquarter staffs or in combat units. In this connection, and with the thought in mind of any future conflicts, the following outline has been contributed on our profession's position in the military organization.

1. The Army sharply distinguishes between Command and Staff functions. Geology's place pertains to the functions of the Staff.

2. Geology is of maximum usefulness in two Staff offices, namely, the Intelligence Division on the General Staff and the Intelligence Division under the Unit Engineer.

3. In the Zone of the Interior (War Department jurisdiction) the main center for geological work should be in the Intelligence Division. Office Chief of Engineers. A smaller team of geologists, supplementing work done in M.I.D., O.C.E., should be attached to G-2, War Department General

Staff. In order to extend this geological service to the Ground, Air, and Service Forces, there should be one or two administrative geologists attached to the Intelligence Division of the Commanding General of each of the three Forces. The duties of these administrative geologists would be liaison—to assess the geologic needs of the three Forces and to arrange for obtaining needed service from M.I.D., O.C.E.

4. In a Theater of Operations the main center for geological work should be in the Intelligence Division under the Theater Engineer. A smaller team should be detailed from that Office to G-2, G.H.Q.

5. Geological service needed in the Communication Zones should be provided by the temporary detail of geologists from the Staff of the Theater Engineer to the Staff of the Chief Engineer, Com. Z.

6. In the combat zone the main center for geological work should be the Intelligence Division, Army Engineer. A geologist could be detailed from the Staff of the Army Engineer to G-2, Army. A geologist should also be attached to the Staff of the Corps Engineer. Geological service needed by units smaller than a Corps or in the Army Service Area could be met by temporarily detailing geologists from headquarters to the particular unit.

7. Geologists on these terms should serve in a civilian capacity.

Advantages:

Such an organization plan would enable the geological service to be rendered by coordinated teams rather than scattered groups or individuals acting independently.

The plan enables geologists to service all stages of military planning from the highest level of strategic planning down to and including tactical planning and necessary consulting service on the ground.

The plan provides for geologists assisting where geological service is needed and provides an orderly mechanism for extending the Service to War Department offices and to units in a Theater of Operations, having need for the Service.

Supervision of the techniques and standards of work would remain with the civilian specialists, but the work would be kept under general military control and direction. The plan also leaves to the specialists the initiative for recommending where the specialized service would be useful.

The plan also avoids wasting professional talent by providing that geologists be returned to the main center when a particular geologic job has been completed.

One of the greatest stumbling blocks to the use of geology in military operations was the almost complete lack of understanding or unfamiliarity with the science of geology by many of the officers. In this connection one of our objectives is the teaching of geology in all military schools, not with the idea of trying to make geologists of the students, but to give them a working knowledge or an appreciation of its application. The vice-chairman and his associates have been working on this for some time and even though they have been given the "brush off" in some cases, have made material progress in many others. They have been also working on a textbook for such purposes.

The work of the United States Geological Survey as outlined by W. H. Bradley in the February *Bulletin* of A. A. P. G. in connection with the "Veteran's Retraining Program in Geology" is highly commended. It is our hope that such a program will be expanded to include training in many Colleges and Universities in our country.

In order for us as a profession to receive the proper consideration of the usefulness of geology to military problems and how geological service can be fitted into the complex military organization, we must agree among ourselves on a single plan, and in addition thereto cooperate with and enlist the support of other geological societies in formulating a final plan to present through the proper channels.

SPECIAL ACTIVITIES

In the division of special activities, vice-chairman Gulley has attempted to keep abreast of new developments on the legislative front which might affect A.A.P.G. members in service or returning therefrom. He has also followed the progress of national science legislation, since this also had a bearing upon the work of the committee, inasmuch as one of the Association's permanent objectives is the incorporation of geologic instruction in military training. An attempt has been made to feel the pulse of local Selective Service boards, generally, on the practical effects of changes in selective service regulations. Mr.

Gulley has also tried to keep an ear to the ground for the development of any lines of thought in the public mind, or in the minds of the members of our profession, which might provide leads to be pursued by the committee in securing for geology and geologists proper recognition in modern military operations. While many matters along these several lines have been in process of development during the Association year, none appears to have progressed to concrete conclusions of major significance. This should not be taken to indicate, however, that there has been little activity or progress. This is one of the functions which the national service committee has been trying to perform and which should be continued by the Association regardless of whatever decision is made as to a continuance of the national service committee.

VETERANS' RE-EMPLOYMENT

The vice-chairman, A. R. Denison, reports that up to the present time the re-employment of veterans has not been a serious problem. The oil companies were requested to file their needs with the headquarters office; however, the responses were few; also only a small number have filed their applications. In most cases the latter have found employment. There still remain a number who, on account of unusual restrictions on the location and the type of work they will do, have not found employment. The most pressing needs of the oil companies are: (1) geologists to do foreign work; (2) geologists to work on geophysical parties; and (3) specialized men with training in certain fields as, for example, Tertiary micropaleontologists.

From observation prior to January 1, 1946, practically all qualified men were absorbed by the oil industry, but since then, there seems to be a lessening in the rate of hiring. The latter situation may be due to several factors—(1) a large number of men have already been hired; (2) many more geologists may have returned to former or other employers than anticipated and have not notified the headquarters office. Certainly more than 250 out of 740 in military service have returned. In the event that not more than 50 per cent have returned, the problem of re-employment may become more difficult and require greater efforts in their placements.

Most of the affiliated and local geological societies are cooperating very effectively in the re-employment program, and much more can be done by those which have not been active in this respect. As an example and model of excellent and efficient organization in working out this problem in the affiliated societies, the following is quoted from a letter of Olin G. Bell, Houston Geological Society, and a member of the national service committee to R. A. Steinmayer, New Orleans Geological Society, and also a member of this committee.

> This society (Houston Geological Society) at the beginning of this administrative year, set up a placement committee composed exclusively of ex-servicemen which committee was charged with functions of canvassing the organizations in this area which have openings for returned ex-servicemen with geological training or experience. Mr. John D. Todd is chairman of this committee.
>
> Any returned serviceman with geological training or experience who is seeking work is referred to this committee which has currently at hand the names of organizations which have or might have openings and the ex-servicemen have been referred to these places and advised whom they should contact in each organization.
>
> This committee has so far done an excellent job and fortunately has been instrumental in guiding the ex-servicemen to contacts which have led to their employment. They have been able to place many of the young geologists who went into the Armed Service immediately upon completing their geological training and are now seeking their first professional job. In addition, they have been instrumental in placing several geological draftsman in geological departments and also in helping some students attending the University of Houston classes in Geology in finding part-time work.
>
> It so happens that several of the companies are taking on a number of new employees and have thus been unable to absorb most of the boys so far returned. It also appears that several of the geophysical concerns need additional help and are willing to take on some of these young ex-servicemen and we have recommended to them that they take some of these geophysical assignments even though it is not the work they would ultimately want to follow.

With respect to veterans who have been handicapped by injuries or other causes from returning to their former positions or specialities, very few cases have been called to our attention. Any case of this character would receive the immediate attention of the local groups wherever possible and sponsor rehabilitation through the Veterans' training program or any other assistance, keeping in mind retention in some kind of geological work, if possible.

MEMBERS OF A.A.P.G. IN ARMED FORCES

TABLE I

MEMBERS OF A.A.P.G. IN ARMED SERVICES OF UNITED STATES AND ALLIED NATIONS
(March 9, 1946)

	Privates Non-Com. Officers	*Lieuts.*	*Capts.*	*Majors*	*Colonels*	*Total*
Army Air Corps	30	71	55	26	14	196
Infantry	14	11	6	6	2	39
Corps of Engineers	28	26	16	16	5	91
Artillery—all types	7	17	14	5	3	46
Ordnance	0	2	2	2	3	9
Signal Corps	3	2	1	2	0	8
Quartermaster Corps	1	1	3	2	1	8
Other branches and unclassified	2	15	23	11	6	57
Unclassified as to rank and branch	—	—	—	—	—	28
Total Army	85	145	120	70	34	482
Marine Corps	4	4	8	1	—	17

	Misc.	*Ensigns*	*Lieuts.*	*Comdrs.*	*Capts.*	*Total*
Navy	25	50	146	16	1	238
Coast Guard	—	—	2	—	—	2
Merchant Marine	—	—	—	—	—	1
Total Armed Forces						740
Released from Service						250*
Killed in action or died while in service						13

* This number have notified Headquarters, but there is probability that an additional 100 to 200 have not done so.

The statistics of Table I include only those members about whom we have information but do not include members who have not notified us of entering or being released from military service.

In connection with Table I you will note that as of this date 740 have entered the service, as compared with 423 on February 1, 1943. An interesting comparison is that they favored the Army over the Navy approximately 2:1, but the most interesting feature, not shown in the table, is that a majority of our members chose the Army Air Corps and Engineers and Naval Aviation. At the time that a majority of them entered the service, the best opportunities for them then available were in Photo Intelligence of the Army Air Corps and Navy. Both of these branches of service gradually accumulated more and more geologists as the War continued and many others succeeded in being transferred into Photo Intelligence and the Corps of Engineers. Others entered or were transferred into Fuels and Lubricants section of the Quartermaster Corps and the Rehabilitation of Oil Fields section of the Corps Engineers. When the final analysis of the experience records has been compiled, an interesting history can be told of our members in the Armed Forces.

There can be no doubt that the services performed by our members in any branch of service were valuable contributions to the military war effort. In addition to the work of

the Geological Unit of the U.S.G.S. the men in Photo Intelligence did some remarkable work in assisting in the offensive planning operations of both the Army and Navy.

You will note from Table I that we have a record of 13 members who were killed in action, or died in military service. It is very appropriate on this occasion that we pay them our highest honor and praise, and sympathy for their families, and in addition thereto that this list be now entered as a part of this report.

Lt. Edward Benjamin Baldwin, El Paso, Texas, died on January 1, 1945, at the Naval Hospital, Pasadena, California.

Lt. John F. Barnett, Jr., was killed in Italy on October 13, 1944. He was with the 34th Division at the time. His home address was Palacios, Texas.

Lt. Edgar R. Breed, Jr., formerly with the Shell Oil Company, Inc., Centralia, Illinois, was reported missing in action when the U.S.S. *Chevalier* was sunk. We were notified that he had been officially declared dead on July 5, 1945.

Major William Palen Conway, Jr., formerly with the Phillips Petroleum Company, Houston, Texas. In November, 1945, we were notified that he had been killed in a plane crash in February, 1944. Major Conway had been with the Weather Section, Headquarters, 13th Air Force in the Pacific.

Captain Robert Hamilton Cuyler, assistant director of the Army Air Forces, Ground Training Technical Advisory Unit, Central Instructors School, Randolph Field, Texas, was killed in an airplane accident near Blanco, Texas, on March 13, 1944, while on a training mission. Captain Cuyler was formerly associate professor of geology at the University of Texas.

Captain Adolph T. Eberhardt, formerly with the Shell Oil Company, Inc., Evansville, Indiana, was killed in a plane crash early in 1944, according to information received from the office in Evansville on July 5, 1945. The last military address we had for Captain Eberhardt was Public Relations Office, Robins Field, Georgia.

Lt. Nolan A. Fanguy, U. S. Army Air Corps, was killed on August 22, 1942, in an airplane crash near Key Field, Meridian, Mississippi. He was formerly employed by the Shell Oil Company, Inc., and his home was in Houma, Louisiana.

Major Linn M. Farish of Woodland, California, was killed in a plane crash on September 11, 1944, while on a surveying trip in the Balkans.

Captain Donald Alexander Fullerton, formerly with the Indian Oil Concessions, Ltd., was drowned when his boat capsized while he was engaged in military exercises around Karachi, India. Word of his death was received in December, 1942. He had been serving in the Duke of Wellington's Regiment.

Major John Muro Golden, formerly with The Elflex Company, Houston, Texas. On December 8, 1945, we were notified that he had been killed in an auto accident in Germany. Major Golden was with the 1265 Engr. Bn. at the time of his death.

Lt. Col. Donald Frost Newell, formerly with the Phillips Petroleum Company, Corpus Christi, Texas, died in a hospital in Brisbane, Australia, on December 7, 1944, apparently from a pistol wound in his knee.

Lt. Mark Lafon Orr, formerly with the Sinclair Prairie Oil Company, Tyler, Texas, who was reported missing in action on April 13, 1945, has been officially declared dead. He was in the Naval Air Force.

Lt. John Walter Reiss was killed in South Wales on June 4, 1943. He was formerly with the Stanolind Oil and Gas Company, Houston, Texas.

MEMBERS OF A.A.P.G. IN CIVILIAN CAPACITIES WITH GOVERNMENT IN WAR EFFORT

This report would not be complete without praising the work of our members as civilians in Government Service, directly connected with the War Effort. Most of them (about 200 in number) were associated with, and devoted their entire time to, important

war programs of the United States Geological Survey, Petroleum Administration for War, Bureau of Mines, and Bureau of Economic Warfare. In addition to the foregoing members, many others were consultants or devoted part of their time to the work of Government agencies. Practically all members not in Government Service were working overtime on the development, production, and discovery of petroleum reserves, which were vital and necessary for the successful prosecution of the war.

COMMENTS AND RECOMMENDATIONS

An outline of the objectives of the present national service committee and a general discussion of each has been presented to you. The work of each vice-chairman has not been, nor could it have been, completed during this year, so that what we are reporting here is in the nature of a progress report. We are still in a reconversion period, and, even though hostilities have ceased, probably not more than 50 per cent of our members have returned to a civilian status, so that plenty of work remains to be done. We still have Selective Service, release of geologists from the services, unfinished analysis of veterans' records, teaching of geology in military schools, recommendations for application of geology to military operations, geology's place in the military organization, assistance in the re-employment of veterans, and keeping up to date on legislative developments affecting the profession.

Near the end of World War I geology was finally recognized as a valuable and important contribution to successful military operations and the conservation of military manpower. After the peace, this hard-earned position of geology was soon forgotten. No effort was made on our part to maintain and strengthen our position, so that when World War II started we were back to the first round of the ladder. During the early part of World War II, the same struggle for recognition existed, regardless of all efforts on our part and other geological organizations. Later, after conclusive demonstrations of our ability to assist in most types of military operations, the profession really "went to town." Now that we have attained this high esteem, we should capitalize on all our former lessons and mistakes by going forward in expanding and increasing our potentialities in this respect. In order to meet emergency requirements of any future situations, our profession should work out our own plan in order to insure that geologists will serve this country as geologists in teaching, government, industry, and the military forces.

After consideration of all factors and the objectives involved, the national service committee recommends to the incoming executive committee that this special committee be continued for another year.

F. L. AURIN, *chairman*

EXHIBIT X. REPORT OF COMMITTEE ON APPLICATIONS OF GEOLOGY

During the past year I have been in communication, at one time or another, with all the members of the committee and can state that some progress was made in helping to carry out the aims for which this committee was organized. Several items of interest came to the committee's attention, primarily, a suggestion from the Dallas Geological Society that "air logs" or maps be discussed at our forthcoming meeting. The proposal is under consideration.

It has been pointed out that the Federal Radio Commission has recently been taking an active interest in the time allocated various radio stations and it has been intimated that the Commission wants more cultural programs. This matter was brought up briefly at the last meeting of our committee before the war.

It has been recommended, particularly by Paul Weaver, that a central library at A.A.P.G. headquarters be set up in Tulsa for the purpose of cataloging all kinds of lantern

slides and other illustrative data. These data would be available to the membership as interested.

It has also been suggested that a review of technical movies be cataloged and printed in the *Bulletin*. For example, such educational films as "Oil for To-morrow" are not called to the attention of all our members as soon as published. There are several such films in the possession of various oil companies that could be obtained upon application.

It is the consensus of this committee that scientific exhibits should be fostered and it has been suggested that scientific exhibits might well be fostered as a prize contest subject in our colleges.

The committee recommends that the A.A.P.G. should try to catalog and perhaps publish the theses on petroleum geology submitted in partial requirements for degrees. This effort would serve to encourage the students and bring their work before the community.

I will be happy to supplement this report immediately after the convention.

J. BRIAN EBY, *chairman*

EXHIBIT XI. REPORT OF MEDAL AWARD COMMITTEE

The medal award committee was unable to meet in conference the past year, but performed its functions under the prescribed rules by correspondence.

Medal Award.—The medal award committee submits the following report, arrived at by the unanimous opinion of the award committee and concurred in by the executive committee:

No recipient for the Sidney Powers Memorial Award has been chosen for the year 1945 (1) because of the fact that insufficient funds are in the income account of the Medal Fund to cover the cost of the medal and diploma and (2) because of the following rule.

"The income only from the fund shall be used for the purchase of the medal and no award shall be made unless sufficient funds are available." (This *Bulletin*, June, 1943, page 879, paragraph 5 under fund.)

President's Award.—The President's Award was established and the rules for the selection of a recipient annually were approved by the executive committee on October 8, 1944, and were published in the January, 1945, *Bulletin*.

The award consists of $100 in cash plus a citation, and is given to the author of the article published in the *Bulletin* during the preceding year which made the most significant contribution to petroleum geology. To be eligible an author must not have reached his fortieth birthday on January 1 of the year in which his article appears.

In 1945, the Association published in the *Bulletin* 13 papers by 17 authors that were eligible for the President's Award. Through a series of preferential mail ballots the article, "Subsurface Stratigraphy of Atlantic Coastal Plain between New Jersey and Georgia," by Horace G. Richards (July, 1945, *Bulletin*), was judged by the committee to have made the most significant contribution to petroleum geology. After approval by the executive committee, the author, Horace G. Richards, was declared the recipient for 1945. This the second President's Award was made by appropriate ceremony on April 3, 1946, at the 31st annual meeting of the Association, in Chicago, Illinois.

The chairman expresses his thanks and appreciation for the fine cooperation of the whole committee in performing its functions during the past year.

FRANK R. CLARK, *chairman*

EXHIBIT XII. REPORT OF COMMITTEE ON BOY SCOUT LITERATURE

The committee has been attempting by correspondence among its members, with president Cheney, and with Boy Scout National headquarters, to develop ideas and a plan.

The ideas so far developed may be summarized as follows.

1. The Boy Scouts offer an excellent long-range opportunity to increase public understanding of geology and the work of the geologist, an opportunity of which the maximum possible advantage should be taken, in order to capture the interest of bright young boys in the appeal of geology as a profession.

2. The only present Boy Scout work in or connected with geology is a merit badge award in rocks and minerals, using a well written but rather technical and difficult pamphlet. The work is for advanced Scouts and has not been popular. Thus only a few Scouts are being given any geologic guidance.

3. It should be possible, if the right approach is made, to develop as much interest in geology as in other nature studies such as ornithology and botany.

4. We believe the right approach is not to start with rocks and minerals, which we think is the hard way, but to start with the things a Scout can see if he gets a few blocks off the city streets. We believe, in other words, that the right approach is through physiography rather than mineralogy.

5. We believe that through this approach geologic work could start with the youngest Scout and carry through to the most advanced, through a properly graduated series of pamphlets.

6. The pamphlets should lead the Scoutmaster to start with the nearest creek or gully, and explain progressively through the years what the creek or gully does, how it came to be where it is, why the hills are hills and the valleys valleys, what becomes of the load the creek carries, what types of rocks may be formed from the load, the types of rocks from which the load was derived, the types of soil that each type of rock makes, the types of minerals that compose these rocks, other rocks and other minerals, the useful minerals, in what types of rocks are various minerals formed, why are such minerals as coal and oil found in one type of rock, metals in other types, and finally what lies beneath the surface of the earth below the depths to which mines and wells go. The story as thus presented would cover the whole of geology.

7. The advantage of such an approach is that it starts with the everyday and visible, and for the most part stays there. Only toward the end need it take most Scouts more than ten miles from home, and then the local coal dealer, filling station, stone cutter, and museum can supply much visual material.

8. We believe that interest could properly be aroused and augmented by including in the pamphlets, especially in the introductory parts, something of the appeal of geology as a profession, as well as the cultural and utilitarian value of geologic knowledge.

9. The only response so far received from Scout Headquarters is a request to revise the present pamphlet on rocks and minerals. The committee's present feeling is that such a revision should wait until the over-all plan is more fully developed and the petrological and mineralogical part can be unified with it. We doubt that a merit badge award on rocks and minerals can be made popular except as a development of more general geologic knowledge acquired in previous scout years.

10. Requests made last year to Scout Headquarters for a reaction to the approach here suggested, and for Scout literature on other natural sciences, have as yet received no response. This is not particularly surprising. The national officials probably have no more knowledge than most people that geology is not an abstruse science valuable only to miners and oil men, but instead is an active ever-present force that impinges on everyone's daily life and helps to explain what he sees whenever he gets off the pavement, even into the subway. To sell them such an idea will doubtless require personal discussion, particularly after a plan has been more definitely formulated and some material prepared.

11. The committee feels that the project is distinctly worthwhile and should be pursued with considerable vigor.

It is further recommended that this committee be enlarged to include more geologists who can contribute ideas and material for final manuscript presentation to the national Boy Scout officials.

MAX W. BALL, *chairman*

EXHIBIT XIII. REPORT OF RESEARCH COMMITTEE

In order to save time and for the additional purpose of concentrating on our recommendations, I propose to give only a skeleton review of the year's activities. However, it should be emphasized that these recommendations rest on a carefully considered foundation. The chairmen, members, and consultants of the subcommittees have produced results which reflect the great amount of time and thought that they have put into the survey and analysis of their subjects.

STATEMENT OF YEAR'S ACTIVITY

Three short paragraphs will be enough to recall the year's activity.

1. The objectives, agenda, schedule, committee organization, and suggested scope of subcommittee investigation were described in a report which was published under Research Notes in the October *Bulletin*. They need not be recapitulated here.

2. A mimeographed report of 154 pages on the progress of the work of the subcommittees as of January 15, was distributed to past and present members of the research committee, past and present officers of the Association, present members of the business committee, and four copies were sent to the president of each local society affiliated with the Association. It is planned to make available, at cost, a near-print edition of the revised final report.

3. Reports on the progress of discussions concerning research policy and the role of the Association in research have been mimeographed and given the same distribution as already outlined. Special articles on research have also been mimeographed from time to time and distributed to members of the research committee and those others who have requested them. Forty-seven pages of special reports and forty-nine pages of articles on research have been mimeographed. The total of mimeographed page copies, including the January 15 Progress Report is 106,450. Total cost to the Association of mimeographing, mailing, cutting stencils, and other stenographic expenses has been $1,475.

SURVEY AND PROGRAM

This year, the research committee has had two assigned objectives.

1. To complete a reconnaissance survey of research in petroleum geology and allied sciences, with specific reference to exploration.

2. To formulate a comprehensive research program which the Association may adopt as its recommendation for that research most needed to improve our ability to find oil.

We believe that the the preliminary purposes of the first objective have been achieved and that it will not be necessary to continue the survey of research in full force for another year. There are, however, several subjects, not now included in our program, which appear to need further consideration by special subcommittees. Furthermore, the subcommittee on regional projects is visualized as an "idea scouting section," which would provide liaison between the research committee and local groups. So constituted, it would provide a partial continuation of this year's survey.

Several of the subcommittees have made reconnaissance surveys of their respective fields and have developed extensive lists of pertinent questions, suggestions and potential projects. From these we have formulated a program which is composed of eight large projects, several recommendations for federal and state surveys, and numerous research activities which we believe should be commended, encouraged, and kept in mind as pos-

sible future projects. Our large fundamental projects are not formulated to the blue print stage but we believe that such formulation could be completed during the coming year. It is our recommendation that the major activity of the incoming committee should be directed toward the blueprinting of these major projects.

MAJOR PROJECTS

(The order of occurrence of the projects in the following list is not intended to indicate an order of importance. The occasion has not yet arisen which could necessitate establishing priorities.)

Clay Minerals project.—The identification, description, parameters, and behavior of clay minerals in sedimentary rocks as related to all types of well logging, core analyses, reservoir behavior, source beds of petroleum, base exchange, indices of sedimentation environment and variations in permeability, porosity and fluid saturation with burial and compaction.

Hydrocarbons project.—An effort will be made to establish valid indices of the evolution of petroleum as determined by stratigraphic age, depth of burial and original depositional environment. Accepted indices will be applied as criteria of suggested hypotheses of the origin, migration and accumulation of oil.

Formation Waters project.—Application of established and new techniques to a systematic program of analysis of formation waters in selected depositional basins in search of possible gradients or trends in water composition which may lead to new criteria for the discovery of oil.

Bacteria project.—Investigation of the occurrence and activity of bacteria in reservoir fluids as an aid to the appraisal of the role of bacteria in the formation and transformation of petroleum hydrocarbons.

(Related or parallel experiments are being conducted as a part of A.P.I. Research Project 43A, but the aforementioned project proposal would not duplicate efforts.)

Modern Sediments project.—The investigation of sediments of the northern part of the Gulf of Mexico with reference to the physical, chemical, and biological factors in the environment, deposition, and diagenesis.

Ancient Sediments project.—Comprehensive study of the sediments of a single limited stratigraphic section over a considerable area.

Carbonate Rocks project.—The study of the nature and manner of origin of porosity and permeability in carbonate rocks.

Cementation project.—The investigation of the cementation of sedimentary rocks and its bearing on oil occurrence.

Salt Dome project.—Map the flow structure of the interior salt mines.

RECOMMENDATIONS TO OTHER AGENCIES

The following projects are thought to have special merit as "background research" in exploration, and it would be helpful to the research program if their value were called to the attention of the appropriate agency.

1. Completion of topographic map of the United States, and presentation on both large and small scales (for example 1:62,500 and 1:500,000).

2. Completion of geologic map of the United States and presentation on both large and small scales (for example 1:62,500 and 1:500,000).

3. Increase of density of gravimetric base stations to one station to 2,500 square miles; interconnect pendulum stations with gravity-meter traverses and adjust network to 0.1 milligal accuracy; run gravity-meter profiles across major second-order gravity anomalies and across major tectonic features of the United States.

4. The plan of the National Research Council committee on paleoecology as applied

to marine sediments to prepare a book on paleoecology.

5. The Fuels Section, United States Geological Survey, State survey, and individuals for their publication of regional paleoecology maps.

6. The proposed preparation of a revision of the Treatise on Sedimentation by the National Research Council committee on sedimentation.

A detailed list of questions, suggestions and projects will be presented in the final report of the committee.

ROLE OF ASSOCIATION IN RESEARCH

One of the most prominent sets of limiting conditions to constructing a workable research program that would be acceptable to the Association is the difference of opinion that exists among the members about the role which the Association should play in research. In an attempt to find the average view we have conducted a survey of opinion on this subject.

It has been urged that the role of the Association in research should be in harmony with its basic character as a group of individuals, banded together to exchange their views in conferences and through the medium of their publications. The object of these conferences and publications is to advance our ability, to the end that we may improve our performance in the practice of petroleum geology.

Research projects which are sufficiently restricted in size to be conducted by individuals and study groups would appear to form the backbone of the research of the A.A.P.G. Ideas are born of individual effort and small groups of individuals who are interested in the same problem.

Some projects, however, are naturally related to others and can be treated best by a team. In some instances, the facilities which are needed are not available outside of major research laboratories. This type of group project may be of such wide scope and long term as to be unattractive to single industrial laboratories. Such problems would seem to form the basis for cooperative research and we believe that the A.A.P.G. may properly concern itself with projects of this type.

We, as an Association of petroleum geologists, are primarily interested in the application of geology to the discovery and recovery of oil. There is, however, a wide range of possible projects within the applied research field, ranging from "background" to "fundamental." Our interest in applications—immediate and ultimate—does not limit our program to "industrial research." In fact, it would seem to be advisable to avoid the "industrial" field, except insofar as cooperative action appears to be desirable.

Much research has been done by individuals or groups within the Association. Such activity appears to be in conformity with our interest and with the Association's constitution, but it does not appear to be to our interest to assume the responsibilities of a research foundation. It is recommended that the Association should not attempt to *do* major research projects but that we should *catalyze* them by formulating such major projects and attempting to place them with existing research agencies.

We further recommend that the Association should make funds available for the expenses involved in formulating such projects, subject to the judgment of the executive committee. Estimates of next year's expenses range from $2,000 to $5,000.

Several major projects have been recommended which are more cartographic than "fundamental" or "applied" research in character, but they are strongly urged as being fundamental to research and it would seem to be a shortsighted policy to quibble over terms and eliminate them from our schedule when they are highly pertinent to our aims. Many of these are projects which might be of interest to Government bureaus or surveys. We recommend that each project in this class, which has been favorably acted on by the executive committee, should be called to the attention of the appropriate agency by the

Association. The extent to which this Association should go in its recommendation would, of course, rest with the executive committee in each specific case.

ACKNOWLEDGMENTS

I want to take this opportunity to thank the chairmen, the members and the consultants of the subcommittees. They have fulfilled our stated objectives which appeared, in the beginning, to be too elaborate to warrant expectation that they would be accomplished this year. It would be difficult to express adequate appreciation for their cooperation, but I do give them my very sincere thanks.

Several of the local societies have been very helpful in supplying us with statements of the research needs of their areas and by submitting partial formulation of programs. Several hundred members have contributed generously of their time and advice by letter and in numerous conferences. To all of these I wish to express my thanks, and the hope that they will continue to give their support to the development of our research program.

SHEPARD W. LOWMAN, *chairman*

EXHIBIT XIV. REPORT OF GEOLOGIC NAMES AND CORRELATIONS COMMITTEE

The geologic names and correlations committee now functions largely through three subcommittees named Post-Cretaceous, Mesozoic, and Paleozoic. It is intended that these subcommittees will continue indefinitely with rotating membership. Their purpose is to continuously study the use of geological names and correlations in the various ages of rocks and to stimulate discussion and research in all ways possible.

The geologic names and correlations committee was originally created to join with similar committees of other geological orgaizations in the preparation of a set of rules of nomenclature. When the rules were completed the committee was continued to see that the new rules were properly policed. At later dates a Permian subcommittee and then a Carboniferous subcommittee were created to study and report on specific problems. When their reports were complete those two subcommittees were disbanded. It was apparent from the results of the valuable work done by the Permian and Carboniferous subcommittees that there was a need for the continuous study of the use of geologic names and correlations.

In our science it is impractical to write a final report on any system of names and correlations. Therefore, the geologic names and correlations committee has created and put into operation, first, the Post-Cretaceous subcommittee, then the Mesozoic subcommittee, and now in the past year the Paleozoic subcommittee. It is intended that they will continue to function indefinitely with the primary purpose of getting local groups or individual geologists to study and make available data regarding geologic names and correlations. If others publish the necessary data the subcommittees may prepare few reports, but wherever advisable the subcommittees may prepare charts and reports.

The Post-Cretaceous subcommittee, under W. Armstrong Price, started its work in Texas several years ago and has extended its work eastward as much as possible. It has now received correlations charts from South Texas, the Houston district, northwestern Louisiana, southwestern Louisiana, Mississippi, and western Alabama. It still lacks correlation charts for southeastern Louisiana, Florida, southeastern Alabama, and Georgia. It is necessary that a local group be organized in Florida to work with the Post-Cretaceous subcommittee on the preparation of suitable charts for Florida and adjacent parts of Alabama and Georgia. When these various charts are completed the subcommittee still has a big job ahead to properly correlate the regional charts. It is their intention to ultimately prepare a report to include this available data.

The Mesozoic subcommittee has been reorganized during the past year with Henry

J. Morgan, Jr., as chairman, and additional committee members have been appointed to bring it to full strength. Its first project is in the Gulf Coast region where it has started work on a long Mesozoic cross section extending from southern Florida westward through the Gulf Coast region to South Texas. It is to include the deepest most basinward wells that have drilled the most complete sections. Plans also have been made for other cross sections extending from their main cross section updip to the more critical areas along the rim of the Mesozoic embayment, and these will eventually be tied into the outcrops as much as possible. Two of the local geological societies have prepared preliminary prints of their cross sections for this project and they are ready to exhibit.

The Paleozoic subcommittee was newly organized in 1945 with Robert H. Dott as chairman, and is now planning the organization of its work. It has been instructed to promote research and discussion on all problems relating to the nomenclature and correlation of Paleozoic rocks. It has been advised to form local study groups of interested geologists in the various local and regional geological societies. In addition to new problems of nomenclature and correlation, it will continue the work done by the former Permian and Carboniferous subcommittees.

The geologic names and correlations committee has had the same chairman for nine years, which is too long a period for effective leadership. The work has been enjoyable, but in time there is a lack of new ideas and it is necessary that a new chairman be appointed to continue this work.

JOHN G. BARTRAM, *chairman*

EXHIBIT XV. REPORT OF COMMITTEE ON STATISTICS OF EXPLORATORY DRILLING

The committee on statistics of exploratory drilling held its first annual meeting here in Chicago to-day (April 1, 1946).

This is the first report of this committee, which was authorized at the last annual meeting of the Association, and was organized during the summer of 1945. The committee is large, having twenty-three members, distributed throughout the United States. In many districts the main-committee member is chairman of a subcommittee. The total number of geologists helping in the work of the committee is therefore between 70 and 75, and, in addition to these, many scouts, clerks, stenographers, and draughtsmen have assisted. We mention this because, in the first place, emphasis should be placed on the fact that the contributing personnel is very large.

In the second place, we would call attention to the fact that thoughtful analysis of the data which are gathered in each district is essential for their proper classification and study. The work of the committee is not merely a listing of data. It is a careful investigation in each district, terminating in a comparative study of all this information by the chairman. For those who may be interested in figures, we may state that in the 1945 reports received from our committee members in all parts of the country approximately 50,000 items were recorded. These items are entered on forms of which there are five, one for each of the five classes of exploratory hole. The total number of sheets prepared on these five forms by the committee was 515 with an average of 10 holes recorded on each.

Due to the facts (1) that all statistics for the year just closed are usually not available until as late as the middle of February, (2) that compilation and study of the statistics from the several districts require a great deal of time, and (3) that the report on these statistics is wanted for presentation at the Association annual meeting, it devolves upon the chairman to carry out this final duty and to write the final report; and there is no time for the committee to go over this report before it is submitted. This is unfortunate, but it is unavoidable. However, in assuming responsibility for any errors or deficiencies in the final report, to be printed in the June number of the *Bulletin*, the chairman wishes to make clear that the bulk of the work was done by the other members of the committee,

to whom great credit is due. Obviously, without their constructive cooperation, nothing worthwhile could have been accomplished.

Although we believe that the value of the work of this new committee is evident to most of our Association members, we have noted that a few seem unable to appreciate this value. For the most part they seem to be those who can measure values only in dollars soon to be received. We want to explain that such a yardstick should not be applied to this committee's results. If there is any one thing in which all our Association members should be interested, it is an annual overall appraisal of the outcome of our recommendations for seeking new oil and gas reserves. And the only way in which this can be done is by gathering and correlating the data on exploratory drilling throughout the country. This annual summary will grow in significance as the years go by. It is an undertaking which by all means should be continued as long as petroleum geology has a reason for maintenance. With this summary available, there is not a progressive company in the petroleum industry, which does not annually measure its own results of exploration against the average results of the country as a whole. These statistics provide a uniform and authoritative standard of reference. Furthermore, they are of considerable assistance as a background for the papers on development, which have become a regular contribution to our *Bulletin*. We add with pleasure that the members of the committee, collectively and individually, have expressed much satisfaction in this opportunity which they have of adding to their own knowledge and in serving this Association and the Industry through the results of their efforts.

F. H. LAHEE, *chairman*

EXHIBIT XVI. REPORT OF COMMITTEE FOR PUBLICATION

In the past fiscal year, the committee for publication arranged by correspondence for the preparation of 18 papers describing oil and gas developments in the United States and Canada during the calendar year 1945. Abstracts of the papers were printed in the program of the annual meeting of the Association at Chicago, April 1–4, 1946, and the chairman of the committee, at the request of the executive committee, presented an oral summary of the papers at that meeting. In addition, the widely scattered members of the committee assisted in obtaining manuscripts for publication in the *Bulletin*.

The committee agrees that it is highly desirable that the Directory of Sources of Basic Geologic Data, by J. V. Howell, vice-chairman of the committee, and A. I. Levorsen, be published promptly by the Association, either as a number of the *Bulletin* or as a special volume.

During the year, J. V. Howell, editor of Volume III, *Structure of Typical American Oil Fields*, and the committee considered further the kinds of data that should be included in that volume.

C. E. DOBBIN, *chairman*

EXHIBIT XVII. REPORT OF REPRESENTATIVE ON DIVISION OF GEOLOGY AND GEOGRAPHY OF NATIONAL RESEARCH COUNCIL, 1945–1946

The annual meeting of the Division scheduled for May 5, 1945, was cancelled because of wartime travel regulations. However, committee reports from the three joint geological and geographical, the 19 geological and the 8 geographical committees were assembled and published in mimeograph form as usual, along with reports from representatives of the seven constituent societies. These reports reveal that some progress was being made even under adverse war conditions.

A supplemental report of the committee on marine ecology as related to paleontology, Harry S. Ladd, chairman, was published, December, 1945, by the National Research

Council (56 pages, price $0.50). Many Association members will no doubt be interested in this committee's plans to prepare a treatise on marine ecology for the use of paleontologists at the earliest practicable date. The present report deals with current activities, a bibliography of recently published papers, and contributions on "Japanese reports," "collecting Recent foraminifera," "diatoms as paleoecological indicators," "possible shallow-water origin of radiolarian shale of the Mount Diablo area, middle California," "paleontological conditions in the Ozark region in Lower Ordovician (Canadian) time," "paleoecology of some oysters," "shallow-water fish faunas from the Miocene of California," "summary of ecological studies on invertebrates of the Texas coast."

Moderate appropriations of Research Council funds were made for the United States committee for the study of Paricutin; the committee on measurement of geologic time, and for expenses as joint host with the Geological Society of America for a "meeting or assembly of representatives of the 13 principal national geological societies" held October 12–13 at the Council's headquarters "to discuss problems of common concern to all geological societies and to lay plans for future joint activities." The Association was represented at this assembly by Ira H. Cram and M. Gordon Gulley. Chairman W. W. Rubey of the Division was drafted as chairman of this conference. Much progress appears to have been made toward a better understanding of purposes, needs and organizational requirements for effective cooperation.

The executive committee of the Division is giving special study to the proper research program for the Division; to the relationship of its research activities to that of other organizations; to the types of committees, that is, long range *versus* projects; and how tenure of committee membership should be regulated. Of special importance is the possible effect upon the Council's activities if the Congress establishes a National Science Foundation generously financed by the Federal Government as recommended in the Bush report (1945) "*Science, the Endless Frontier.*"

The Division is aggressively studying the problem of geological education through a committee headed by Professor Chester R. Longwell. Conferences have been or are being held at annual meetings of the GSA, AAPG, AGU between dates of December, 1945, and May, 1946. It is hoped that important progress can be made on a national scale through these efforts. A similar committee is studying training and standards in the geographical profession.

The committee for map sketching from aerial photographs is planning "a concise yet complete manual of the best *noninstrumental* methods by means of which maps can be constructed from aerial photographs. The Arctic Institute of North America, an international research organization organized with the joint support of the National Research Councils of Canada and the United States, established its headquarters in Montreal in October, 1945.

The American Geophysical Union, which has become a large national scientific society represented in the membership of the Division of Geology and Geography, still maintains its original status, through its Executive Committee, as the Committee on Geophysics of the NRC.

Recent numbers of the *Transactions* of the American Geophysical Union, published by the National Research Council, contain a number of articles, 12 to 60 pages each, of interest to petroleum geologists and geophysicists, such as the following.

"Low-Angle Normal Faults in the Basin-and-Range Province," by Chester R. Longwell
"F. A. Vening Meinesz—A Geodesist's Contribution to Science," by R. M. Field
"Vertical Control Surveys for Reconnaissance Maps," by C. F. Fuechsel
"Problems in Photogrammetry," Earl Church
"National and Regional Work-Potentials," W. T. Thom, Jr.

Special attention will be given to the needs of the Civil Service Commission and other

government agencies as well as to questions related to "higher education and national defense."

M. G. CHENEY, *representative*

MINUTES OF BUSINESS COMMITTEE, STEVENS HOTEL, CHICAGO, ILLINOIS

APRIL 1, 1946

The annual business committee meeting was called to order in the Stevens Hotel, Chicago, Illinois, April 1, 1946, 10:00 A.M., by Robert W. Clark, chairman.

1. Roll call by secretary E. A. Koester showed the following members and alternates present.

Chairman: Robert W. Clark
Vice-chairman: C. L. Moody
Secretary: E. A. Koester
Executive Committee: M. G. Cheney, E. A. Koester, Ira H. Cram, M. G. Gulley (absent), Gayle Scott
Members-at-large: A. Rodger Denison, T. S. Harrison, Earl B. Noble, Edgar W. Owen, H. G. Walter (W. W. Rand)

	Representatives	*Alternates*
Division of Paleontology:	John R. Sandidge	
	Henryk B. Stenzel	
District Representatives:		
Amarillo:	Elisha A. Paschal	
Appalachian:		Paul H. Price
Canada:	Edwin H. Hunt (absent)	
Capital:	Carl H. Dane	
Corpus Christi:	Ira H. Stein (absent)	
Dallas:	Barney Fisher	
East Oklahoma:		T. E. Weirich
	J. L. Borden	
	Glenn D. Hawkins	
Fort Worth:	Lynn K. Lee	
Great Lakes:	Robert M. English	
	Stanley G. Elder	
Houston:	George S. Buchanan	
	Donald M. Davis	
	A. P. Allison	
	P. B. Leavenworth (absent)	
Michigan:	E. J. Baltrusaitis	
New Mexico:	George Vorbe	
New York:	Gail F. Moulton	
Pacific Coast:	Robert T. White	Vincent W. Vandiver
	Elmo W. Adams	
	Rollin Eckis	
	Glenn C. Ferguson	
Rocky Mountain:	Robert L. Sielaff	
Shreveport:	G. D. Thomas	
South America:	L. W. Henry (absent)	
Southeast Gulf:	Henry N. Toler	

Southern Louisiana:	Max Bornhauser	
South Permian Basin:		Leo R. Newfarmer
	John M. Hills	
South Texas:		Thornton Davis
Tyler:	J. S. Hudnall	
West Oklahoma:	Jerry B. Newby	
	Arthur M. Meyer	
Wichita:	John W. Inkster	
Wichita Falls:	Earl M. Stilley	

1. *Seating of representatives.*—It was moved, seconded, and carried that members of the business committee not present at roll call be recorded by the secretary if they report to him at the close of the session.

2. *Minutes of previous meeting.*—It was moved, seconded, and carried that the reading of the minutes of the last meeting of the committee be dispensed with, as they have been published in the *Bulletin.*

3. *Report of distinguished lecture committee, Fred H. Moore, chairman.*—(1) It was moved, seconded, and carried that the report be accepted and referred to the annual business meeting, with the recommendation that it be not read, but that it be published in the *Bulletin.*

(2) It was moved, seconded, and carried unanimously on recommendation of the executive committee that the business committee approve and recommend to the annual business meeting of the Association the following amendment to the by-laws:

(3) Change the by-laws, Article VI, Section 1, first paragraph to read as follows:

"There shall be the following standing committees: business committee; research committee; committee on geological names and correlations; committee on applications of geology; committee for publication; finance committee; committee on statistics of exploratory drilling; trustees of revolving publication fund; trustees of research fund; medal award committee; and DISTINGUISHED LECTURE COMMITTEE."

(4) Add new Section 13 under Article VI of the by-laws, as follows:

"DISTINGUISHED LECTURE COMMITTEE"

"SECTION 13. THE PURPOSE OF THE DISTINGUISHED LECTURE COMMITTEE IS TO ARRANGE, CONDUCT, AND MANAGE A SERIES OF SELF-SUSTAINING, NON-PROFIT LECTURE TOURS AMONG AFFILIATED SOCIETIES AND ASSOCIATION SECTIONS BY OUTSTANDING SPEAKERS ON TIMELY SUBJECTS. THE COMMITTEE SHALL CONSIST OF SEVEN MEMBERS UNLESS A DIFFERENT NUMBER IS AUTHORIZED BY THE EXECUTIVE COMMITTEE."

4. *Report of trustees of research fund, C. L. Moody, chairman.*—It was moved, seconded, and carried that the report be accepted and referred to the annual business meeting, with the recommendation that it be not read, but that it be published in the *Bulletin.*

5. *Report of commission on classification and nomenclature of rock units, C. W. Tomlinson, chairman.*—It was moved, seconded, and carried that the report be accepted and referred to the annual business meeting, with the recommendation that it be not read, but that it be published in the *Bulletin.*

6. *Report of national service committee, Fritz L. Aurin, chairman.*—It was moved, seconded, and carried that the report be accepted and referred to the annual business meeting, with the recommendation that it be not read, but that it be published in the *Bulletin.*

7. *Report of committee on code of ethics, C. W. Tomlinson, chairman.*—(1) It was moved, seconded, and carried that the report of the committee on code of ethics be amended to conform with the recommendations of the executive committee.

(2) It was moved, seconded, and carried that the business committee recommend to the annual business meeting the adoption of the constitutional amendments contained in the report of the committee on code of ethics.

(3) It was moved, seconded, and carried that the business committee recommend to the annual business meeting of the Association that the present code of ethics be abolished if and when the two constitutional amendments, Sections 7 and 8, Article III, are adopted by the membership.

(4) It was moved, seconded, and carried that the business committee recommend to the annual business meeting that the by-laws be amended as recommended by the committee on code of ethics and the executive committee.

(5) It was moved, seconded, and carried that the business committee recommend to the annual business meeting the provisional amendment of the first sentence of Section 5, Article II, of the by-laws to read as follows:

"Charges of misconduct in violation of SECTION 7 OF ARTICLE III OF THE CONSTITUTION shall first be submitted in writing to the president of the Association by a member in good standing, in confidence, with a full statement of the evidence on which the charges are based," such amendment to be made part of the by-laws in the event that the two constitional amendments, Sections 7 and 8, Article III, are adopted.

8. *Report of committee on applications of geology, J. Brian Eby, chairman.*—It was moved, seconded, and carried that the report be accepted and referred to the annual business meeting, with the recommendation that it be not read, but that it be published in the *Bulletin*.

9. *Report of medal award committee, Frank R. Clark, chairman.*—It was moved, seconded, and carried that the report be accepted and referred to the annual business meeting, with the recommendation that it be not read, but that it be published in the *Bulletin*.

10. *Report of committee on Boy Scout literature, Max W. Ball, chairman* (report read by Don L. Carroll).—(1) It was moved, seconded, and carried that the report be accepted and referred to the annual business meeting, with the recommendation that it be not read, but that it be published in the *Bulletin*.

(2) It was moved, seconded, and carried that the business committee recommend to the executive committee that they continue and expand the work of the committee on Boy Scout literature.

11. *Report of committee on method of election of officers, John G. Bartram, chairman* (report read by Ronald K. DeFord).—(1) It was moved, seconded, and carried that the report of the 1946 committee on method of election of officers be substituted for the report of the 1945 committee on method of election of officers and that the 1946 report be accepted and its recommendations as to changes in the constitution be approved and recommended to the annual business meeting for its approval and submittal to the membership by mail ballot.

(2) It was moved, seconded, and carried that the amendments to the by-laws of the 1946 Bartram report of the 1946 committee on method of election of officers be provisionally adopted, such by-laws to become effective upon approval by the membership of the Association of the constitutional changes recommended in the 1946 report.

12. *Report of research committee, Shepard W. Lowman, chairman.*—It was moved, seconded, and carried that the report be accepted and referred to the annual business meeting with the recommendation that it be not read, but that it be published in the *Bulletin*.

13. *Report of geologic names and correlations committee, John G. Bartram, chairman* (report read by H. D. Miser).—It was moved, seconded, and carried that the report be accepted and referred to the annual business meeting, with the recommendation that it be not read, but that it be published in the *Bulletin*.

14. *Report of committee on statistics of exploratory drilling, F. H. Lahee, chairman.*—It was moved, seconded, and carried that the report be accepted and referred to the annual business meeting, with the recommendation that it be not read, but that it be published in the *Bulletin*.

15. *American Association for the Advancement of Science, Section E.*—It was moved, seconded, and carried that the business committee recommend to the annual business meeting that the Association affiliate with the American Association for the Advancement of Science, Section E.

16. *Certificate of Incorporation.*—It was moved, seconded, and carried that the business committee recommend to the special meeting of the Association called for the purpose of considering the amendment of the Certificate of Incorporation of the Association on Thursday, April 4, 1946, at 3:30 P.M., Chicago, Illinois, that Article 2 of the Certificate of Incorporation which now reads as follows:

"2. The objects and purposes for which this corporation is formed are to promote the science of geology in general, but more especially with reference to its application to the discovery and production of petroleum and natural gas; to foster a spirit of scientific research among its members; to maintain a high standard of professional conduct on the part of its members; to protect the public from imposition by inadequately trained or unscrupulous persons; and to promote social intercourse among its members.

"In order to accomplish its objects and purposes, the corporation shall have power to hold meetings for social intercourse and the reading and discussion of professional papers; to circulate among its members, by means of publication or otherwise, the information obtained by this or other means; to provide for the organization and continuation of subordinate branches, either within or outside of the state of Colorado, and either within or outside the United States of America; to hold meetings of its members, and of its managers, either within or outside of the state of Colorado, and either within or outside of the United States of America; to have offices outside of, as well as within, the state of Colorado; to construct, maintain, buy, own, sell, and to rent from others, or to others, such buildings and offices as may, to the executive committee of the corporation, appear desirable in order to accomplish any of its objects and purposes; to provide what qualifications shall be necessary for membership; to provide a classification of membership into two or more classes and the conditions to be attached to each class; to provide the method of electing members; to admit or exclude any person; to expel any person from membership; to provide that membership may be forfeited for non-payment of dues without giving of notice; to provide, and to aid in providing, such entertainment, from time to time, as to the executive committee may appear desirable; to make such prudential by-laws as its members may deem proper in order to accomplish the objects and purposes of the corporation, which by-laws may be divided into two parts, one part to be known as the 'Constitution' and the other part to be known simply as 'By-Laws,' either of which may be adopted, amended, or repealed in accordance with the provisions thereof; and to do any and all other things, and to take any and all other steps, which may be lawfully done or taken by corporations organized under said Sub. Div. XII."

be amended to read as follows:

"2. The objects and purposes for which this corporation is formed are to promote the science of geology, especially as it relates to petroleum and natural gas; to promote the technology of petroleum and natural gas and to encourage improvements in the methods of exploring for an exploiting these substances; to foster the spirit of scientific research among its members; to disseminate facts relating to the geology and technology of petroleum and natural gas.

"In order to accomplish its objects and purposes, the corporation shall have power to hold meetings for the reading and discussion of professional papers; to circulate among its members, by means of publications or otherwise, the information obtained by this or other means; to provide for the organization and continuation of subordinate branches, either within or outside of the state of Colorado, and either within or outside of the United States of America; to have offices outside of, as well as within, the state of Colorado; to construct, maintain, buy, own, sell, and to rent from others, or to others, such buildings and offices as may, to the executive committee of the corporation, appear desirable in order to accomplish any of its objects and purposes; to levy dues, and to receive, disburse and invest moneys in furtherance of its objects and purposes; to provide what qualifications shall be necessary for membership; to provide a classification of membership into two or more classes and the conditions to be attached to each class; to provide the method of electing members; to admit or exclude any person; to expel any person from membership; to provide the conditions under which membership will be forfeited; to provide that membership may be forfeited for non-

payment of dues without giving of notice; to make such prudential by-laws as its members may deem proper in order to accomplish the objects and purposes of the corporation, which by-laws may be divided into two parts, one part to be known as the 'Constitution' and the other part to be known simply as 'By-Laws,' either of which may be adopted, amended, or repealed in accordance with the provisions thereof; and to do any and all other things, and to take any and all other actions, which may be lawfully done or taken by corporations organized under said Sub. Div. XII."

17. *Eastern Section.*—It was moved, seconded, and carried that the business committee recommend to the annual business meeting the establishment of the Eastern Section of the Association; members and associates in good standing, residing in the New York District, to be eligible for membership.

18. *Interstate Compact Commission.*—It was moved, seconded, and carried that the matter of formation of a bureau for the collection of statistical information by the Interstate Compact Commission be referred to the executive committee for consideration.

19. *American Geological Institute.*—It was moved, seconded, and carried that the business committee recommend to the annual business meeting the ratification of the constitution of the American Geological Institute.

Adjourned at 5 P.M.

ROBERT W. CLARK, *chairman*
EDWARD A. KOESTER, *secretary*

MINUTES OF SPECIAL MEETING
STEVENS HOTEL, CHICAGO, ILLINOIS
April 4, 1946

The meeting was called to order at 3:30 P.M., Thursday, April 4, 1946, by M. G. Cheney, president.

On the recommendations of the executive committee and the business committee, it was moved, seconded, and adopted that Article 2 of the Certificate of Incorporation be amended to read as follows.

"2. The objects and purposes for which this corporation is formed are to promote the science of geology especially as it relates to petroleum and natural gas; to promote the technology of petroleum and natural gas and to encourage improvements in the methods of exploring for and exploiting these substances; to foster the spirit of scientific research among its members; to disseminate facts relating to the geology and technology of petroleum and natural gas.

"In order to accomplish its objects and purposes, the corporation shall have power to hold meetings for the reading and discussion of professional papers; to circulate among its members, by means of publications or otherwise, the information obtained by this or other means; to provide for the organization and continuation of subordinate branches, either within or outside of the state of Colorado, and either within or outside of the United States of America; to have offices outside of, as well as within, the state of Colorado; to construct, maintain, buy, own, sell, and to rent from others, or to others, such buildings and offices as may, to the executive committee of the corporation, appear desirable in order to accomplish any of its objects and purposes; to levy dues, and to receive, disburse and invest moneys in furtherance of its objects and purposes; to provide what qualifications shall be necessary for membership; to provide a classification of membership into two or more classes and the conditions to be attached to each class; to provide the method of electing members; to admit or exclude any person; to expel any person from membership; to provide the conditions under which membership will be forfeited; to provide that membership may be forfeited for non-payment of dues without giving of notice; to make such prudential by-laws as its members may deem proper in order to accomplish the objects and purposes of the corporation, which by-laws may be divided into two parts, one

part to be known as the 'Constitution' and the other part to be known simply as 'By-Laws,' either of which may be adopted, amended, or repealed in accordance with the provisions thereof; and to do any and all other things, and to take any and all other actions, which may be lawfully done or taken by corporations organized under said Sub. Div. XII."

The meeting adjourned at 3:38 P.M.

M. G. CHENEY, *president* EDWARD A. KOESTER, *secretary-treasurer*

MEMBERSHIP APPLICATIONS APPROVED FOR PUBLICATION

The executive committee has approved for publication the names of the following candidates for membership in the Association. This does not constitute an election but places the names before the membership at large. If any member has information bearing on the qualifications of these nominees, he should send it promptly to the Executive Committee, Box 979, Tulsa 1, Oklahoma. (Names of sponsors are placed beneath the name of each nominee.)

FOR ACTIVE MEMBERSHIP

Frederick Augustus Baumgarten, Jr., Sulphur, La.
James A. Moore, Willard Gill, W. R. Farley

Bernard Mayes Bench, Denver, Colo.
J. Harlan Johnson, W. S. Levings, F. M. Van Tuyl

John Mackintosh Browning, Guayaquil, Ecuador, S. A.
Charles A. Durham, O. C. Wheeler, F. H. Edmunds

Mont Granderson Calvert, Jr., New Orleans, La.
Morgan J. Davis, W. A. Maley, Adolph Dovre

Frederick Macklin Carlisle, Los Angeles, Calif.
John C. Hazzard, Joseph Jensen, Quay S. Diven

Robert Doyle, Midland, Tex.
Leo R. Newfarmer, R. C. Spivey, Samuel P. Ellison, Jr.

Ronald Kenneth Lanyon, Amarillo, Tex.
Wayne M. Felts, Stanley B. White, J. C. Finley

Archer H. Marx, Houston, Tex.
Marcus A. Hanna, C. H. Sample, C. H. Ritz

Mario Rafael Marino-Proby, Caracas, Venezuela, S. A.
Adrian E. Mix, Roy W. Pearce, Frank L. LeRoy

John Lyle McManamy, Mt. Vernon, Illinois
C. E. Brehm, E. E. Rehn, R. C. Cooper

Gordon Rittenhouse, Morgantown, W. Va.
W. C. Krumbein, F. J. Pettijohn, James H. C. Martens

Willard A. Sanger, Saginaw, Mich.
Charles K. Clark, Edward J. Baltrusaitis, Carl C. Addison

Nathaniel Bernard Sauve, New York, N. Y.
B. O. Winkler, G. F. Kaufmann, George F. Barnwell

Harold Wright Stoneman, Mansfield, La.
Harry M. Buchner, George A. Musselman, George Wagoner

Lester William Strock, Saratoga Springs, N. Y.
Alfred C. Lane, John L. Rich, H. Ries

FOR ASSOCIATE MEMBERSHIP

Man Matthew Aycardo, Jr., Manila, P. I.
F. M. Van Tuyl, W. S. Levings, Ben H. Parker

John Seaward Baker, Union, N. J.
Carl C. Branson, Ernest Guy Robinson, William S. Pike, Jr.
Ewart Merlin Baldwin, Portland, Ore.
R. E. Stewart, Charles Nevin, H. Reis
Mary Jane Cole, Oklahoma City, Okla.
John Theron Sanford, W. L. Moreman, F. E. Wimbish
William George Dady, Casper, Wyo.
M. D. Hubley, W. S. McCabe, C. T. Jones
Malcolm Deisenroth, Jr., Tulsa, Okla.
H. C. Arnold, E. F. Miller, Charles F. Hewett
Harry George Hadler, Wichita, Kan.
W. A. Ver Wiebe, Kenneth J. Reid, C. G. Lalicker
Roy Paul Hardy, Columbia, Mo.
D. L. Blackstone, Jr., W. D. Keller, E. B. Branson
Charles Henry Ise, Wichita Falls, Tex.
Lynn L. Harden, J. J. Russell, Jr., Leland W. Jones
Richard Louis Jodry, Lake Charles, La.
A. L. Morrow, W. R. Canada, B. M. Choate
Jack Kirby Larsen, Jackson, Ala.
Dan E. Holland, Fred M. Bullard, William W. Rand
John Landrum Loftis, Jr., Houston, Tex.
L. T. Barrow, Morgan J. Davis, Dean F. Metts
Walter Scott Martz, Jr., Fort Worth, Tex.
H. C. Arnold, D. T. Richards, F. A. Melton
Clyde Franklin Morningstar, Midland, Tex.
E. W. Vanderpool, Charles F. Henderson, Samuel P. Ellison, Jr.
John Walter Olson, Stanford University, Calif.
L. A. Nelson, A. I. Levorsen, A. C. Waters
Sinon Philip O'Rourke, Casper, Wyo.
George H. Gaul, Donald E. Edstrom, Robert L. Sielaff
Clyde Marion Pederson, Odessa, Tex.
Philip D. Larson, L. E. Patterson, Jr., Leroy T. Patton
William Justin Plumley, La Junta, Colo.
Carey Croneis, F. J. Pettijohn, M. W. Fuller
Victor Jean Taylor, Tulsa, Okla.
Ward C. Bean, John E. Galley, A. C. Trowbridge
Gerald Homer Tefft, Tulsa, Okla.
John W. Daly, Charles Edwin Riddell, Homer C. Moore

FOR TRANSFER TO ACTIVE MEMBERSHIP

Warren Lytle Calvert, Oklahoma City, Okla.
John Janovy, Walter L. Moreman, Joseph M. Clark
William Henry Cardwell, Corpus Christi, Tex.
Lloyd G. West, C. C. Miller, Dale L. Benson
Rogert James Gutru, Mt. Pleasant, Mich.
R. L. Kidd, A. K. Wilhelm, Z. E. Stucky
John Edward Kilkenny, Bakersfield, Calif.
Alfred W. Vitt, W. D. Kleinpell, Norman L. Thomas
Walter Hill Marshall, Jr., Shreveport, La.
C. C. Clark, W. C. Spooner, L. D. Bartell
Boyd Ferguson Murphy, Tyler, Tex.
Ray F. Youngmeyer, R. M. Trowbridge, C. I. Alexander

Robert Henry Paschall, Bakersfield, Calif.
James W. Sheller, Glenn C. Ferguson, R. B. Hutcheson
David Holcomb Scott, Portland, Ore.
Francis D. Bode, James R. Dorrance, L. B. Snedden
Sam Stewart, Los Angeles, Calif.
Clifton W. Johnson, H. W. Hoots, Frank A. Morgan
James Ernest Wilson, Jr., Houston, Tex.
Gordon H. White, R. E. McAdams, M. S. Metz

BULLETIN OF THE AMERICAN ASSOCIATION OF PETROLEUM GEOLOGISTS
VOL. 30, NO. 5 (MAY, 1946), PP. 802-806, 1 FIG.

MEMORIAL

THE GEOLOGIST IN WORLD WAR II—A MEMORIAL[1]

A. RODGER DENISON
Tulsa, Oklahoma

It is altogether proper that we pause briefly during this, the first peace-time convention, to pay tribute to those of our members who have contributed directly or indirectly to the military achievements which brought to an end the greatest of all wars. It is likewise desirable to ponder the problems which confront us in keeping the peace and preventing another war.

Wars are fought with the products derived from oil and gas. During the one just ended the demand for these products forced production far above any peace-time year. The American oil industry not only supplied every need of our own armed forces but also supplied our allies as well. Our ability to furnish this oil reflects the high quality of our exploratory and discovery effort as well as efficient management and operation of the technical and working staffs of the producing, refining, and transportation divisions of our industry. Thus, each member of the Association—every geologist, geophysicist, and petroleum engineer—can take his measure of praise for assistance in supplying the sinews of war. Many of our members took an active part in work even more directly related to the war effort, and share in the honor accorded such workers.

The men who engaged in essential production for war made a contribution vital to winning the war, but the service of no man in civilian life is comparable with that of the man who offered his life for his country. More than 700 of our members entered the armed forces. The majority of these saw action abroad where they were exposed to the danger and hazards of the elements and the enemy. Many met the foe in combat in the air, on the sea, or on the ground, and in every case exhibited the daring and courage which is a heritage of our forebears.

The Association can indeed be proud of the war record of our members. A superior understanding by geologists of terrain and field conditions as well as adaptability to a wide diversity of tasks enabled many of our members to perform their assignments with exceptional brilliance.

To all of these men we now express our full appreciation and acknowledge our deep debt of gratitude.

A large number of such men have now been released from their military duties and many are with us to-day to receive personally our tribute to their efforts. A few, however, have not, and will never, return—theirs is the supreme sacrifice which must come to some who engage in the hazards of war. These men we shall enshrine in our hall of memories, reserved for those who during the course of our history have given their all, that we might live. The names of these men are:

FORD FREDERICK BACHMAN	NOLAN A. FANGUY
EDWARD BENJAMIN BALDWIN	LINN MARKLEY FARISH
JOHN F. BARRETT, JR.	DONALD ALEXANDER FULLERTON
EDGAR R. BREED, JR.	JOHN MURO GOLDEN
WILLIAM PALEN CONWAY, JR.	DONALD FROST NEWELL
ROBERT HAMILTON CUYLER	MARK LAFON ORR
ADOLPH T. EBERHARDT	JOHN WALTER REISS

May we now rise and stand with bowed heads in silent tribute to these honored dead.

(Pause)

As we resume our seats let us record our firm resolution to make every possible effort for, and contribution to, a lasting peace.

[1] A memorial service conducted at the 31st annual meeting of the Association, Chicago, April 2.

ROBERT W. BURGER

(1906–1945)

The death of Robert W. Burger on September 25, 1945, following a cerebral hemorrhage, brought to an end, at the age of 39, an outstanding scientific career in its most productive years. Through his unusual ability for critical observation, his sound judgment, and his many years of geologic mapping, Robert Burger had acquired an understanding of Pacific Coast Cretaceous and Tertiary geology rivaled by few.

Robert was born in New Castle, Pennsylvania, on May 25, 1906, and moved with his family to Los Angeles, California, in 1909. He grew up in Los Angeles attending both grammar school and high school there. In 1923 he graduated from Jefferson High School, and in the fall of that year entered Pomona College where he became active in both scholastic and athletic endeavor.

Known better as "Bush" to his friends, Robert became interested in geology during his undergraduate years at Pomona College. There, through his close association with Professor A. O. Woodford he developed a keen insight into this subject which became his life work. The independent approach, and critical attitude that he developed toward scientific problems during these years was apparent throughout all his later work.

After graduation from Pomona College in 1927 he spent two years in graduate study at the University of California. In May, 1929, he joined the geological staff of The Texas Company where he served in the capacity of field geologist in California, Oregon, and Washington for a number of years. During his first summer Robert mapped the geology of the Jalama Ranch near Point Conception, California. It was here that he met Alice Brown of Klamath Falls, Oregon. They were married three years later, in 1932. Up until 1936 Robert was engaged principally in geological mapping, but with his transfer in that year to the San Joaquin Valley the scope of his work was broadened to include subsurface studies. During the years that followed, he rapidly acquired a knowledge of the geology of the Great Valley of California, and with this experience he developed into an exceptionally well rounded petroleum geologist. In 1942 he was appointed district geologist for The Texas Company. He assumed the responsibilities of this new position with his characteristic energy, executing the administrative and advisory duties in such a manner that he won the confidence and lasting respect of all who worked with him. He continued his geological studies also, and at the time of his death had completed a comprehensive series of paleogeographic maps of the Great Valley.

Prior to his work in the San Joaquin and Sacramento valleys, his geologic mapping and stratigraphic studies included work in and adjacent to the Santa Barbara Basin, the Los Angeles Basin, and the Imperial and Salinas valleys of California. Of particular interest were the results of his work in the Imperial Valley, a region in which little systematic geological study had been done. Here he mapped, measured, and segregated the Tertiary rocks of that basin into their stratigraphic units. Among other things, his observation that several thousand feet of Tertiary sediments buttressed against a steep Basement Complex surface, was a contribution to the interpretation of the geology of California, for this same condition, where recognized in other places, had often been erroneously interpreted prior to this discovery as being due to faulting. In addition to his California studies he did extensive work in the Tertiary section of western Oregon and Washington, where he spent some three years unravelling the little known and obscure structure and stratigraphy of the Coastal province of that region. The results of this pioneering work have formed the background for his company's present extensive exploratory program in the Pacific northwest.

Robert's natural tendency for independent thinking and his intellectual curiosity were stimulated during the early years of his work with The Texas Company by his association



ROBERT W. BURGER

with the late Ralph D. Reed. In return, his own observations and ideas had a strong influence on, and were a great aid to Ralph Reed in the preparation of *Geology of California* and *Structural Evolution of Southern California*. A map on page 121 in the latter, showing the geology of the San Joaquin Hills in the Los Angeles Basin is one isolated example of this, but in itself is no measure of the whole influence of his comprehensive research.

With a collector's love for books, he built up a large scientific library, and spent much of his spare time reading. In this he covered not only various phases of geology but many other unrelated subjects, among which was botany, astronomy, and Indian culture of the southwestern United States, this latter being a particular hobby.

With all his intellectual pursuits, Robert Burger was endowed with an unusual measure of the human qualities that make for good fellowship. Captain of his football team in college, he retained always his enthusiasm for athletics and outdoor sports. He enjoyed swimming and fishing, was an ardent handball player, and in recent years had taken up golf with his usual zest. This rare balance between serious purpose and the capacity for relaxation, combined with a homely philosophy, inspired the admiration of all his associates and drew to him many warm and lasting friendships.

Outstanding in his character was a strong sense of loyalty, a high degree of personal and intellectual honesty, and a good sense of humor. Never hampered by personal ambition or desire for recognition, the motivating force in all his work was the desire to satisfy his own curiosity. He was truly a geologist for the love of geology. This most exhilarating personality will surely endure always in the memories of his friends.

Robert Burger is survived by his widow, Alice Brown Burger, his father, Howard Burger, and a sister, Mrs. George Stancer.

ROLLIN ECKIS

BAKERSFIELD, CALIFORNIA
March 19, 1946

KENNETH MASON BRAVINDER

(1907–1946)

Kenneth M. Bravinder died, January 22, 1946, in Long Beach, California. He was born, May 10, 1907, in Dakota City, Iowa, and came to Long Beach in 1926.

Kenneth started his college studies in 1926 at Pomona College, Claremont, California, where the science of geology attracted him. This same subject led him to the University of Southern California in 1929 and it was there that he received his A.B. degree in geology in 1930.

After a summer at Stanford University as a teaching fellow, he entered the University of Washington at Seattle. There he studied under Charles E. Weaver and in 1932 received his M.S. degree in geology. His thesis for this degree was entitled "Stratigraphy and Paleontology of the Oligocene in the Eastern Portion of the Puget Sound Basin." His preliminary work and oral examinations were completed for his Ph.D. at the University of Washington.

During the summer of 1931, he was a ranger naturalist at Mt. Rainier National Park. This was nearly a perfect time for him as he enjoyed and appreciated the mountains. In this work he led tourist parties through the Park and lectured on its history.

In 1933 he was a graduate student and teaching fellow for a year on the Berkeley campus, University of California. He was an excellent teacher in that he had the rare ability of conveying his knowledge to his students in an easily understandable manner.

He started working in 1936 for the Union Oil Company at the Dominguez paleontological laboratory near Los Angeles, California, and continued in that department until 1939.

At this time he was appointed subsurface geologist for the company and was in this position at the time of his death. His principal studies had been made on the Dominguez oil field and the associated fields on the Inglewood-Newport shear.

He became a member of the A.A.P.G. in 1937 and contributed a paper to the *Bulletin* in March 1942, concerning the effect of a current earthquake on certain producing wells in the Dominguez oil field.

Kenneth's friendship and nice sense of humor will be missed by all those who knew him.

He is survived by his wife, Gladys Bravinder, his eight-year-old son, Keith, a two-year-old daughter, Judith, and his father, E. B. Bravinder of Long Beach.

His family plans to stay at its home, 725 East Bixby Road, Long Beach, California.

GILBERT T. BOWEN

LOS ANGELES, CALIFORNIA
March 20, 1946

BULLETIN OF THE AMERICAN ASSOCIATION OF PETROLEUM GEOLOGISTS
VOL. 30, NO. 5 (MAY, 1946), PP. 807-812

AT HOME AND ABROAD

CURRENT NEWS AND PERSONAL ITEMS OF THE PROFESSION

NORBERT A. PARKER resigned on March 8 from his position as geologist with the Stanolind Oil and Gas Company at Lake Charles, Louisiana, to become geologist with the E. I. du Pont de Nemours Company, Wilmington, Delaware.

C. H. GERDES, who has been with the Petroleum Administration for War at Washington, D. C., since 1943, has accepted a position with the United Geophysical Company, Pasadena, California.

P. A. MEYERS is associated with Claude B. Hamill at 909 Second National Bank Building, Houston, Texas, after 10 years in the geological department of the Pan American Production Company.

WILHO J. KIVI is working for the Mountain Fuel Supply Company, Rock Springs, Wyoming, since his release from the Corps of Engineers last November.

THOMAS C. BARGER is with the Arabian Gulf Oil Company, Bahrain Island, Persian Gulf.

The Rocky Mountain Association of Petroleum Geologists, Denver, Colorado, had as its speaker, H. D. THOMAS of the Department of Geology, University of Wyoming, "Late Paleozoic and Early Mesozoic Stratigraphy of the Uinta Mountains, Utah."

MAX BORNHAUSER, Continental Oil Company, Lafayette, Louisiana, spoke on "Marine Sedimentary Cycles of the Tertiary in the Mississippi Embayment," before the Houston Geological Society, April 8.

H. B. RENFRO, of Tulsa University, gave a lecture on "Geology of Coral Islands," at the meeting of the Tulsa Geological Society, April 1. The lecture was illustrated with kodachrome slides made from photographs which Renfro took while in the South Pacific.

A.A.P.G. DISTINGUISHED LECTURE TOUR

W. H. TWENHOFEL, professor emeritus of geology, Wisconsin University, spoke before the following affiliated societies, giving his lecture, "Geology of the Region of the Gulf of St. Lawrence."

March 29—Appalachian Geological Society, Charleston, West Virginia
April 6—Illinois Geological Survey and University Group, Urbana, Illinois
8—Illinois Geological Society, Mt. Vernon, Illinois
9—Indiana-Kentucky Geological Society, Evansville, Indiana
11—Kansas Geological Society, Wichita, Kansas
12—Oklahoma City Geological Society, Oklahoma City, Oklahoma
15—Tulsa Geological Society, Tulsa, Oklahoma
17—Panhandle Geological Society, Amarillo, Texas
19—North Texas Geological Society, Wichita Falls, Texas
22—Dallas Geological Society, Dallas, Texas
23—Fort Worth Geological Society, Fort Worth, Texas
24—West Texas Geological Society, Midland, Texas
26—Houston Geological Society, Houston, Texas
29—South Texas Geological Society, San Antonio, Texas
May 1—East Texas Geological Society, Tyler, Texas
2—Shreveport Geological Society, Shreveport, Louisiana

3—New Orleans Geological Society, New Orleans, Louisiana
6—Mississippi Geological Society, Jackson, Mississippi
8—Southeastern Geological Society, Tallahassee, Florida

LOUIS FRANKLIN, Houston independent geologist and drilling contractor, is leaving for Jerusalem, Palestine, where he is taking charge of the oil exploration program for the Jordan Exploration Company, Ltd. His foreign address is the Jordan Exploration Company, Ltd., Box 773, Jerusalem, Palestine.

JOHN E. GAFFNEY has been transferred to El Dorado, Arkansas, by the Lion Oil Company and can be reached by writing Box 1298.

The annual meeting of The Branner Geological Club was held on March 15 at the California Institute of Technology in Pasadena. This being the twenty-fifth anniversary of the Club, RALPH ARNOLD, a charter member and the first president, was called upon to tell of the formation of the Club and to review the life of JOHN CASPER BRANNER. STANLEY HEROLD presented a framed photograph of Dr. Branner to the Club. Officers elected at this meeting for the ensuing year are: W. C. PUTNAM, U.C.L.A., president; W. T. WINHAM, Standard Oil Company of California, vice-president; RICHARD TEN EYCK, Continental Oil Company, secretary-treasurer. Retiring officers are: W. P. WOODRING, U. S. Geological Survey, president; C. W. JOHNSON, Richfield Oil Company, vice-presidens; H. RODNEY GALE, U.S.C., secretary-treasurer. The principal address was given by R. DANA RUSSELL, of the University of California Division of War Research at San Diego, on "Geologists and Sonar."

RICHARD A. GEYER, formerly associated with the Woods Hole Oceanographic Institution, Woods Hole, Massachusetts, is now with the Geophysical Research Division of the Humble Oil and Refining Company, Houston, Texas.

The Oklahoma City Geological Society and the Oil and Gas Division of the Chamber of Commerce of Oklahoma City heard HAROLD B. FELL, of Ardmore, Oklahoma, speak on "The Position of the Independent in the Oil Industry," April 15.

Research fellowships for graduate study, and Graduate assistantships, are open in Missouri School of Mines and Metallurgy to properly qualified applicants. Graduate work may be done leading to the Ph.D. degree or degree in mining, metallurgy, ceramics, or geology. Further details concerning these opportunities may be obtained from Professor J. D. Forrester, Chairman, Committee on Graduate Study, Missouri School of Mines, Rolla, Missouri.

A Cretaceous correlation chart of Arkansas, Louisiana, Mississippi, and Alabama, prepared and published by the Mississippi Geological Society, may be obtained by writing to J. B. WHEELER, secretary-treasurer, Box 689, Jackson 106, Mississippi. The price of the chart is $0.50.

THORNTON DAVIS, consulting geologist, Peerless Oil and Gas Company, San Antonio, Texas, was elected president of the South Texas Section of the A.A.P.G. for the year of April, 1946, to March, 1947, at its regular meeting in the Milam Cafeteria, San Antonio, Texas, March 18, 1946. Other newly elected officers are: MARION J. MOORE, Transwestern Oil Company, vice-president; and PAUL B. HINYARD, Shell Oil Company, secretary-treasurer.

HUBERT G. SCHENCK, chief of the Natural Resources Section, General Headquarters, Supreme Commander for the Allied Powers, in Tokyo, Japan, was recently promoted to Colonel, Army of the United States.

C. W. TOMLINSON, of Ardmore, gave a lecture on the "Interrelation of Arbuckle and Washita Facies," and A. M. MEYER, of Shawnee, gave a talk on "Washita Sediments Found in Core Holes and Wells Drilled in Bryan County, Oklahoma," before the Shawnee Geological Society at a meeting held in the Aldridge Hotel, Shawnee, Oklhaoma, on Arpil 11.

FRED H. LAHEE was recently appointed chairman of the committee on petroleum reserves of the American Petroleum Jnstitute, J. EDGAR PEW having resigned as chairman. Lahee has been a member of the committee since its organization in 1936. He is a former editor and president of the A.A.P.G.

The Houston Geological Society held a regional conference at the San Jacinto Hotel, Houston, Texas, April 26, and scheduled a field trip to the Dow Industries at Freeport and to the Texas Gulf Sulphur Company's mining activities at New Gulf on April 27. The conference program included the following: "Forty Years of Gulf Coast Geology," by ALEXANDER DEUSSEN; and the following résumés of developments for the five-year period, 1941 to 1945, inclusive: "Upper Texas Gulf Coast," by GEORGE S. BUCHANAN; "South Texas," by BRUCE SCRAFFORD; "Southwest Texas," by W. H. SPICE, JR.; "East Texas," by C. I. ALEXANDER; "South Louisiana," by R. L. DENHAM; "North Louisiana and South Arkansas," by W. H. SPEARS; "Mississippi, Alabama, Florida," by R. M. HARRIS; "Well Logging," by E. J. HAMNER; "Geophysics," by PAUL WEAVER; "Core Analysis," by J. H. P. CAMPBELL; "Stratigraphy," by MARCUS A. HANNA; and "Production Statistics," by C. D. LOCKWOOD. Following the full day review session, W. H. TWENHOFEL delivered his lecture "Geology of the Region of the Gulf of St. Lawrence."

The Geological Society of America in 1945 established depositories of its publications at public libraries in cities where there are a large number of petroleum geologists and where a depository had not been established at a university. For the information of the members of the A.A.P.G., G.S.A. publications may be found at the following depositories.

California
Bakersfield. Kern County Free Library
Colorado
Denver. Denver Public Library
Indiana
Evansville. Public Library
Kansas
Wichita. Wichita Public Library
Louisiana
Shreveport. Shreve Memorial Library
Mississippi
Jackson. Jackson-Carnegie Library
Oklahoma
Ardmore. Carnegie Library
Bartlesville. U. S. Bureau of Mines Petroleum Experiment Station
Oklahoma City. Carnegie Library
Shawnee. Carnegie Library
Tulsa. Tulsa Public Library
Texas
Amarillo. Amarillo Public Library
Corpus Christi. La Retorna Public Library
Houston. Houston Public Library
Midland. Midland County Library
Tyler. Carnegie Public Library
Wichita Falls. Kemp Public Library
Wyoming
Casper. Natrona County Public Library
Alberta, Canada
Calgary. Calgary Public Library

If there are any other cities with a relatively large number of geologists in which there is no depository of the Society's publications and in which there is a desire for a depository, the Committee on Depositories will be glad to consider establishing depositories in them.

NOMINATING COMMITTEE FOR PROPOSED METHOD OF ELECTION OF OFFICERS

President EARL B. NOBLE has appointed a NOMINATING COMMITTEE, composed of

FRANK R. CLARK, *chairman*
ARTHUR E. BRAINERD
A. I. LEVORSEN
HUGH D. MISER
ROY R. MORSE

to meet the requirements in case the proposed constitutional amendments are approved, changing the method of election of officers. Balloting on these proposed changes is now going on by mail. This premature appointment and this early announcement are necessary this year because of the short time the committee would otherwise have for the consideration of candidates. Individual members or groups are encouraged to submit the names of members who in their opinion are qualified for the various offices, together with sufficient information on their professional and Association work to aid the committee in making its selection. These suggestions should be in the hands of the chairman, FRANK R. CLARK, 1409 Thompson Building, Tulsa, Oklahoma, before July 1, in order that the slate may be completed and published in the September *Bulletin*.

FRED B. ELY, consulting geologist and engineer, died in New York City, March 28, at the age of 63 years.

ROGER H. SHERMAN, formerly assistant manager of the Creole Petroleum Corporation, is a newly elected vice-president of the Standard Oil Company (New Jersey) affiliate. For the past 13 years he has been directing the geological activities of the Creole in Venezuela.

JOHN H. HUNER has resigned his position as State geologist of Louisiana. He is entering private consulting practice. PAUL MONTGOMERY has been appointed acting State geologist.

A. W. AMBROSE has been elected president of the Cities Service Oil Company (Delaware) and the Empire Pipe Line Company. He has been with the Cities Service 23 years.

ROBERT HENDEE SMITH, geologist with The Texas Company at Jackson, Mississippi, was killed in an automobile accident near Delhi, Louisiana. He was 30 years of age.

JOSEPH ZABA has opened a consulting office in the First National Bank Building, Houston, Texas. He was with the Rio Bravo Oil Company 18 years. His field is petroleum engineering appraisals and estimates.

WILFRED H. GEIS, who has been with the Union Oil Company of California for 10 years, has resumed his business of consulting petroleum engineering at Los Angeles, California.

E. M. BUTTERWORTH, of San Francisco, California, has been elected president of the Overseas Petroleum Company.

FRANK BUIE BENNETT, formerly geologist for the Persian Gulf Command, U. S. Army, and later executive officer in the Office of the Foreign Liquidation Commissioner, in Paris, is professor of geology at the University of South Carolina.

Commander GEOFFREY W. CRICKMAY has returned from 13 months of service in the Pacific and is now technical officer at the U. S. Navy Mine Countermeasures Station, Panama City, Florida.

Beginning June 1, the permanent address of L. B. HERRING will be Second National Bank Building, Houston, Texas, where he has an office for consulting work in natural gas and petroleum.

JOHN N. DAHM is with the Creole Petroleum Corporation, Jusepin Camp, Caripito, Venezuela.

W. T. THOM, JR., Princeton University, recently published an article, "National and Regional Work-Potentials, 1790–1958," in the *Transactions* of the American Geophysical Union, Vol. 26, Part 1, pp. 3–11.

EUGENE HOLMAN, president of the Standard Oil Company (New Jersey), addressed the Institute of Latin-American Studies of the University of Texas, April 12, on the subject, "Petroleum and the Industrial Program of Latin America."

PHIL P. GABY has resigned his position as district supervisor for Geophysical Service, Inc., at Fresno, California, and is taking up his new duties as consulting geophysicist for the Standard Oil Company of California. His address is Standard Oil Building, San Francisco.

H. W. BELL, geologist and engineer, has a consulting office for oil, gas, and mining practice, including problems of development, production, and appraisal, at 1136 Wild Rose Drive, Santa Rosa, California.

BERNARDO GROSSLING-FREUDENBURG has left the California Institute of Technology, Pasadena, California, and may be addressed at Casilla 2800, Santiago, Chile.

Lieutenant FORD F. BACHMAN, who was reported as "missing in action over England" in January, 1945, has been declared dead. Lieutenant Bachman was born at St. Joseph, Missouri, April 8, 1916, graduated from the University of Michigan in 1940, and was in the employ of the Stanolind Oil and Gas Company, before he enlisted in the Army in 1941.

New officers of the East Texas Geological Society, Tyler, Texas, are: president, D. R. GUINN, Cities Service Oil Company; vice-president, T. H. SHELBY, JR., Humble Oil and Refining Company; secretary-treasurer, GEORGE ELY, Continental Oil Company.

N. R. LAMB, formerly with the Continental Oil Company at Hobbs, New Mexico, is now petroleum engineer with the New Mexico Bureau of Mines and Mineral Resources, Santa Fe, New Mexico.

WILLIAM WYMAN MALLORY, after completing the residence requirements for the Ph.D. degree at Columbia University, has returned to the Phillips Petroleum Company as research stratigrapher in the division of geological research.

ROY W. MERRITT left the State Department in June, 1944, since in which time he has been with the Socony-Vacuum Oil Company as special representative in South America with headquarters in Bogota. His address is Socony-Vacuum Oil Company, Apartado Nacional 1140, Bogota, Colombia, S. A.

CHARLES F. WORD was discharged from the Navy on November 23, 1945, returned to Midland, Texas, as a geologist for the Gulf Oil Corporation, resigned that position on March 1 and entered into consulting practice with ROBERT G. ANDERSON, who was dis-

charged from the Navy about February 1. Their offices are in the Mims Building, Abilene, Texas.

HERBERT YOHO, recently with the Hanna Ore Company, DeGrasse, New York, is on the teaching staff of the department of geology and geography at the University of Tennessee, at Knoxville.

FRED F. KOTYZA is with the Fullerton Oil Company, Box 532, Roswell, New Mexico.

ROBERT H. DOTT and MALCOLM C. OAKES, of the Oklahoma Geological Survey, Norman, Oklahoma, discussed "The Des Moines, Missouri and Virgil outcrops of East Central and Northeastern Oklahoma," at the meeting of the Oklahoma City Geological Society, April 24.

BURTON E. ASHLEY has been transferred by the Phillips Petroleum Company from Wichita, Kansas, to Denver, Colorado.

RAYMOND C. BECKER, of the Conservation Branch, United States Geological Survey, Denver, Colorado, is on temporary duty with the Military Geology Unit of the Geologic Branch. He is serving as head of the Fuel Branch, Mining and Geology Division of the Natural Resources Section of General Headquarters, Supreme Command Allied Powers, in Tokyo, Japan. His address is NRS GHQ SCAP, APO 500, care of Postmaster, San Francisco, California.

P. E. FITZGERALD of Dowell, Incorporated, left Tulsa on May 2 for Caracas, Venezuela. He will attend a meeting of United Oilwell Service, S. A., of which he is a vice-president and director.

On May 6, ROBERT TOTTEN, Sun Oil Company at Delhi, presented "Geology of the Delhi and West Delhi Fields, Richland Parish," at a meeting of the New Orleans Geological Society.

W. LAYTON STANTON, formerly district chief geologist of the Bakersfield Division of the Union Oil Company, has been transferred to Washington in charge of the Washington and Oregon division of that company. He is headquartered at Olympia, Washington.

The South Louisiana Geological Society wishes to announce that it has for sale a revised Production Map of South Louisiana which shows locations of all producing fields and known salt domes, cumulative production to January 1, 1946, estimated future reserves, number of producing wells, and daily average production for all fields, together with the age of the producing zones for each field. Also shown on the map is a tentative stratigraphic column for South Louisiana, and cumulative production and estimated future reserves for all of South Louisiana. These maps are for sale for $2.50 a copy, and may be ordered from W. R. CANADA, Box 872, Lake Charles, Louisiana.

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Cities Service Oil Company

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Transwestern Oil Company
605 Union National Bank Building

Regular Meetings: 7:30 P.M., Geological Room, University of Wichita, first Tuesday of each month. The Society sponsors the Kansas Well Log Bureau, 412 Union National Bank Building, and the Kansas Well Sample Bureau, 137 North Topeka.

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Secretary - - - - - - - - - Lloyd D. Traupe
Ohio Oil Company

Treasurer - - - - - - - - - D. E. Newland
Magnolia Petroleum Company

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Pure Oil Company
402 2d Natl. Bank Bldg., Saginaw
Business Manager - - - Kenneth A. Gravelle
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Meetings: Bi-monthly from November to April at Lansing. Afternoon session at 3:00, informal dinner at 6:30 followed by discussions. (Dual meetings for the duration.) Visiting geologists are welcome.

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Secretary-Treasurer - - - - - J. B. Wheeler
Stanolind Oil and Gas Company

Meetings: First and third Thursdays of each month, from October to May, inclusive, at 7:30 P.M., Edwards Hotel, Jackson, Mississippi. Visiting geologists welcome to all meetings.

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Secretary-Treasurer - - - - - - Ben S. Curtis
Independent, Box 156

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Vice-President - - - - - Roy D. McAninch
Consulting
Secretary-Treasurer - - - - - Carl A. Moore
Carter Oil Company
1300 Apco Tower

Meetings: Technical program each month, subject to call by Program Committee, Oklahoma City University, 24th Street and Blackwelder. Luncheons: Every second Wednesday, at 12:00 noon, Skirvin Hotel.

SHAWNEE GEOLOGICAL SOCIETY
SHAWNEE, OKLAHOMA

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Schlumberger Well Surveying Corporation
Vice-President - - - - - - Delbert F. Smith
Oklahoma Seismograph Company
Secretary-Treasurer - - - - Marcelle Mousley
Atlantic Refining Company, Box 169

Meets the fourth Thursday of each month at 8:00 P.M., at the Aldridge Hotel. Visiting geologists welcome.

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U. S. Geological Survey, Box 311
Editor - - - - - - - - - Charles J. Deegan
Oil and Gas Journal, Box 1260

Meetings: First and third Mondays, each month, from October to May, inclusive at 8:00 P.M., University of Tulsa, Kendall Hall Auditorium. Luncheons: Every Tuesday (October-May), Chamber of Commerce Building.

TEXAS

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CORPUS CHRISTI, TEXAS

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Tide Water Assoc. Oil Co., Box 1008

Vice-President - - - - - - W. E. Greenman
The Texas Company

Secretary-Treasurer - - - - - O. G. McClain
Southern Minerals Corp., 411 N. Broadway

Regular luncheons, every Wednesday, Petroleum Room, Plaza Hotel, 12:05 P.M. Special night meetings, by announcement.

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Vice-President - - - - - - Willis G. Meyer
DeGolyer and MacNaughton, Continental Building

Secretary-Treasurer - - - - - John M. Clayton
Seaboard Oil Company, 1400 Continental Building

Executive Committee - - - - Fred H. Wilcox
Magnolia Petroleum Company

Meetings: Monthly luncheons by announcement. Special night meetings by announcement.

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TYLER, TEXAS

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Cities Service Oil Company
Box 779

Vice-President - - - - - - T. H. Shelby, Jr.
Humble Oil and Refining Company

Secretary-Treasurer - - - - - George N. Ely
Continental Oil Company
Peoples Bank Building

Luncheons: Each week, Monday noon, Blackstone Hotel.

Evening meetings and programs will be announced. Visiting geologists and friends are welcome.

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FORT WORTH, TEXAS

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2210 Ft. Worth National Bank Bldg.

Vice-President - - - - - Edwin M. Rowser
The Texas Company, Box 1720

Secretary-Treasurer - - S. K. Van Steenbergh
Sinclair Prairie Oil Company
901 Fair Building

Meetings: Luncheon at noon, Hotel Texas, first and third Mondays of each month. Visiting geologists and friends are invited and welcome at all meetings.

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HOUSTON, TEXAS

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Humble Oil and Refining Company, Box 2180

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Stanolind Oil and Gas Company Box 3092

Regular meeting held the second and fourth Mondays at noon (12 o'clock), Mezzanine floor, Texas State Hotel. For any particulars pertaining to the meetings write or call the secretary.

NORTH TEXAS GEOLOGICAL SOCIETY

WICHITA FALLS, TEXAS

President - - - - - William Lloyd Haseltine
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Secretary-Treasurer - - - - John R. Davis
Superior Oil Company, 807 Hamilton Building

Luncheons and evening programs will be announced.

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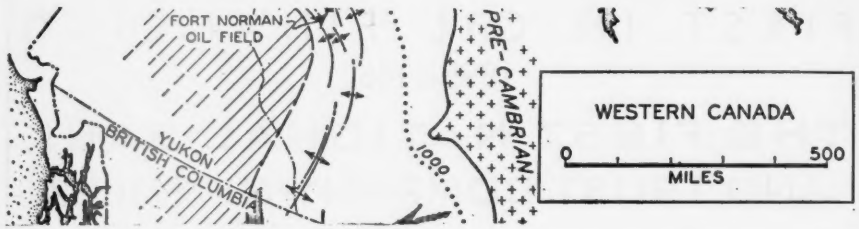
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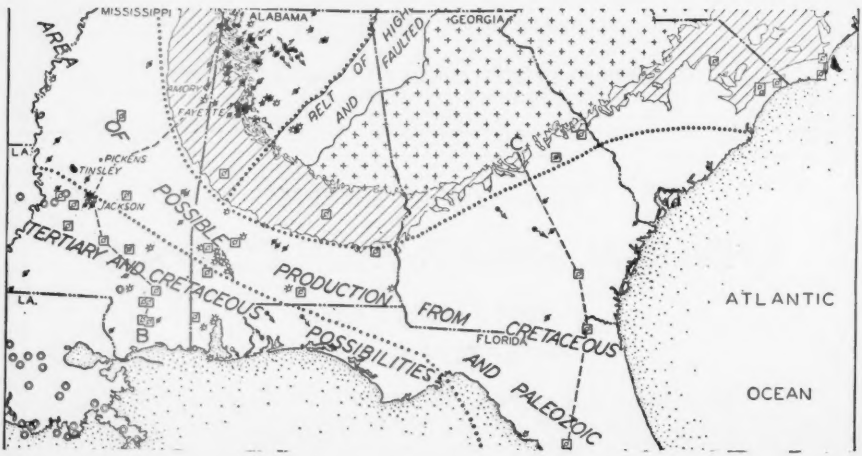
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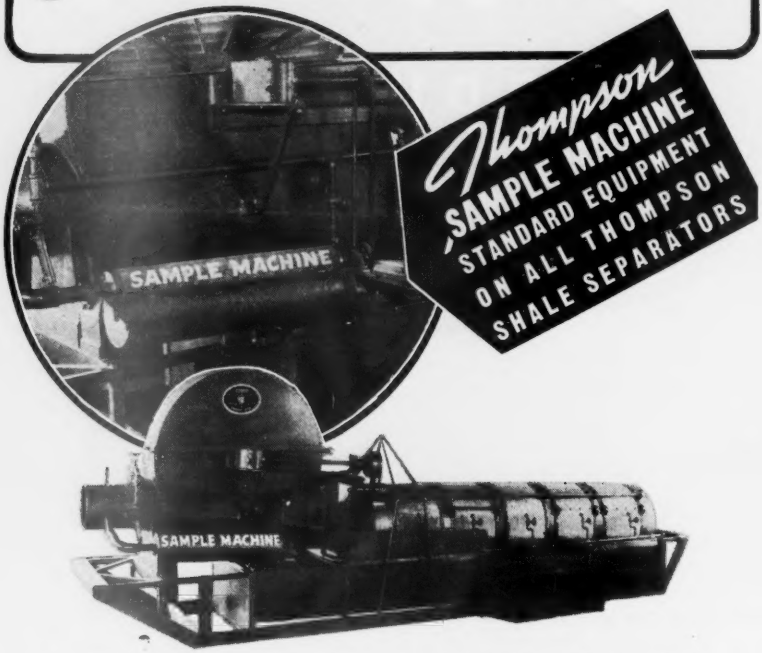
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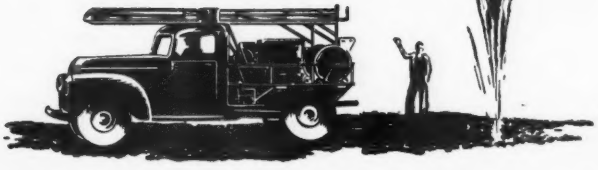
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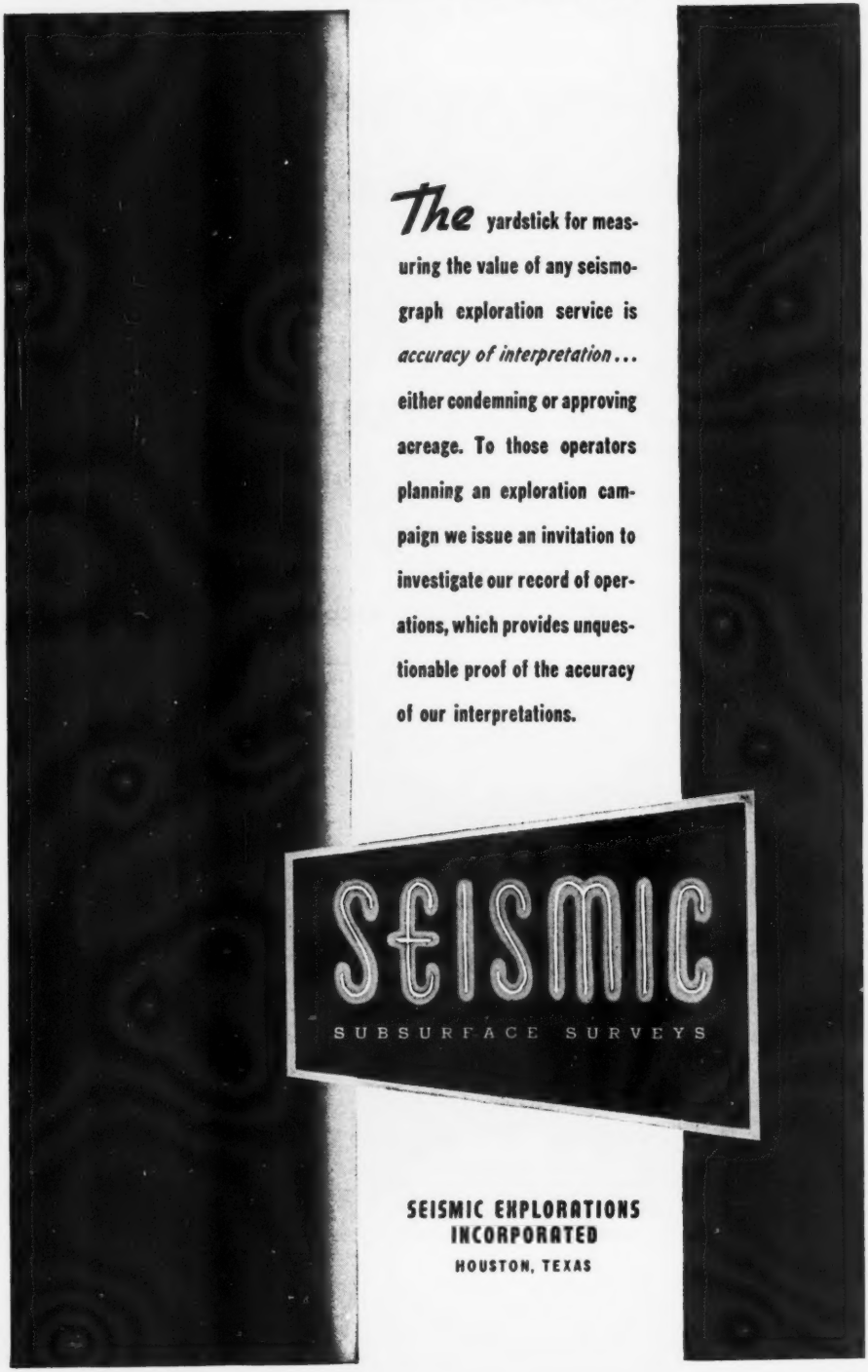
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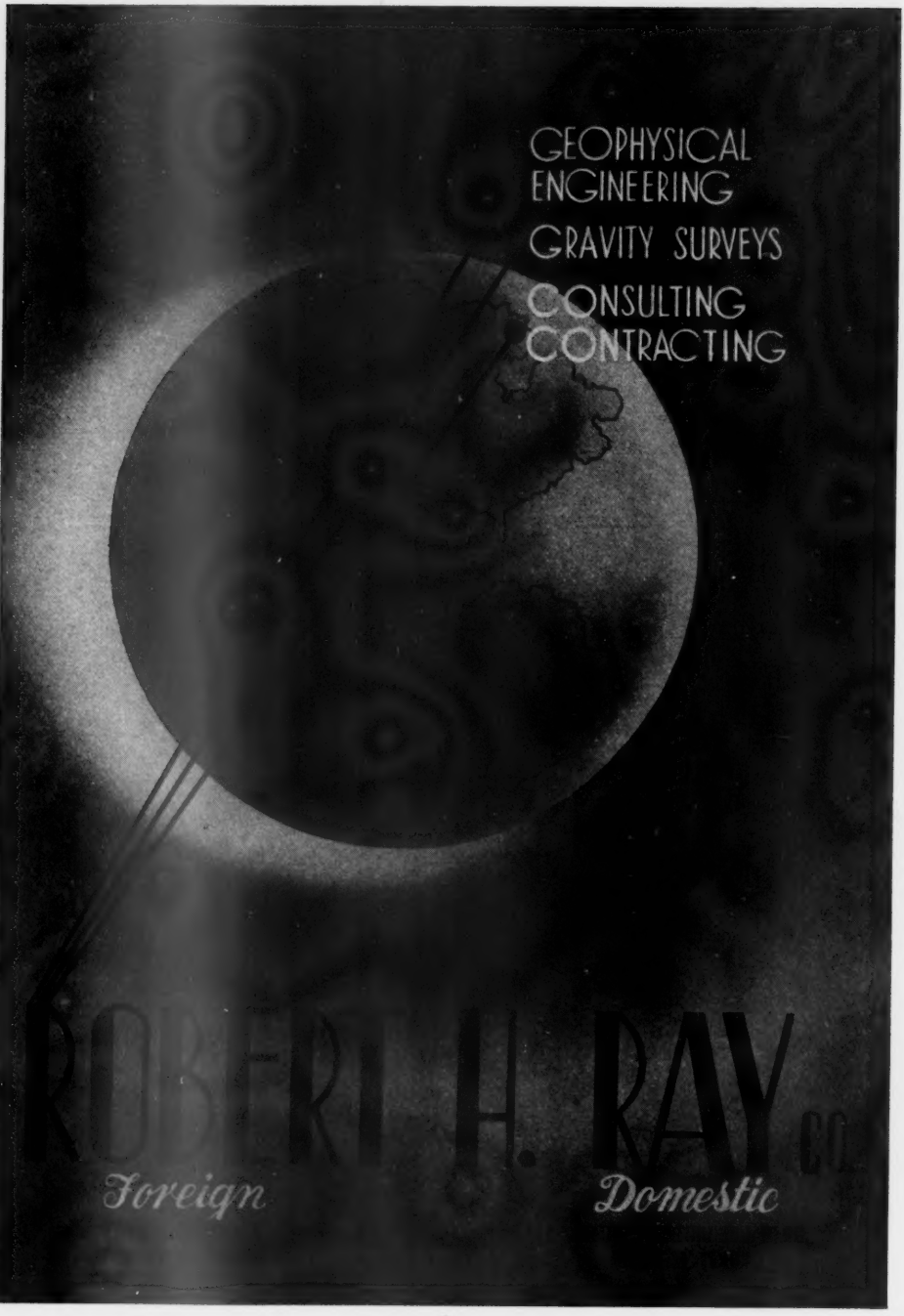


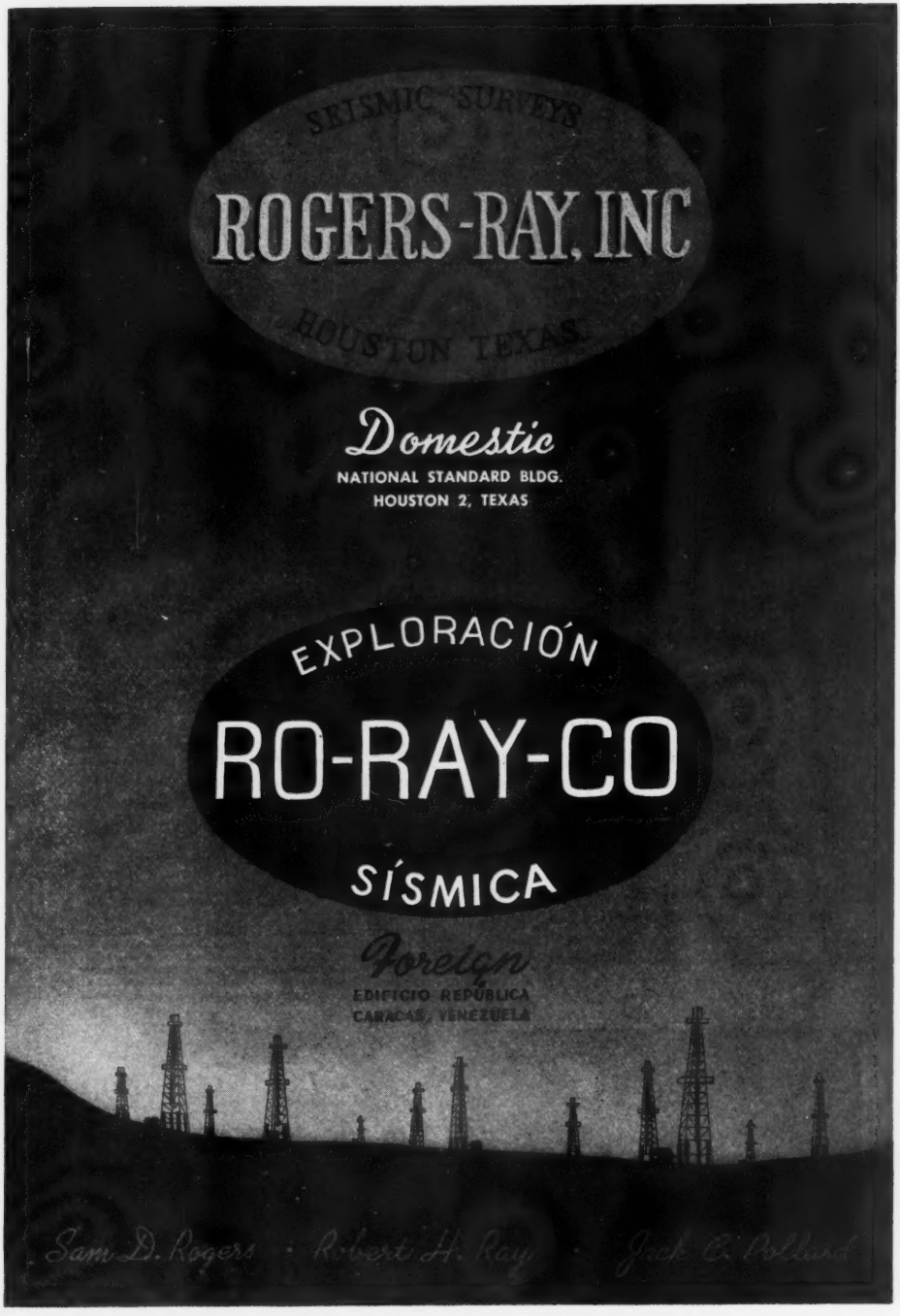
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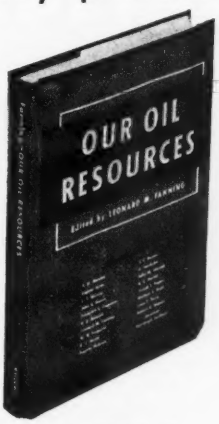
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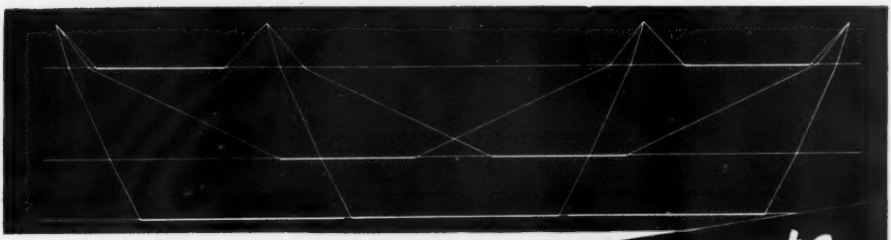
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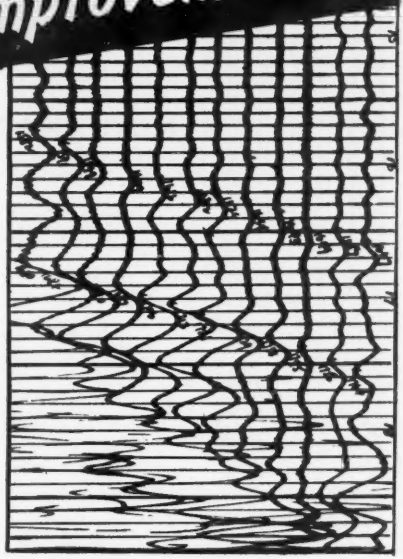
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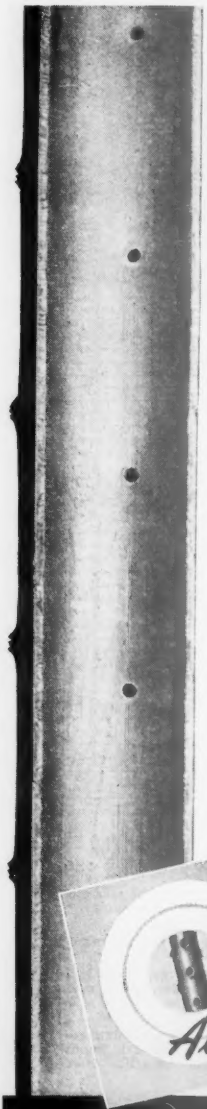
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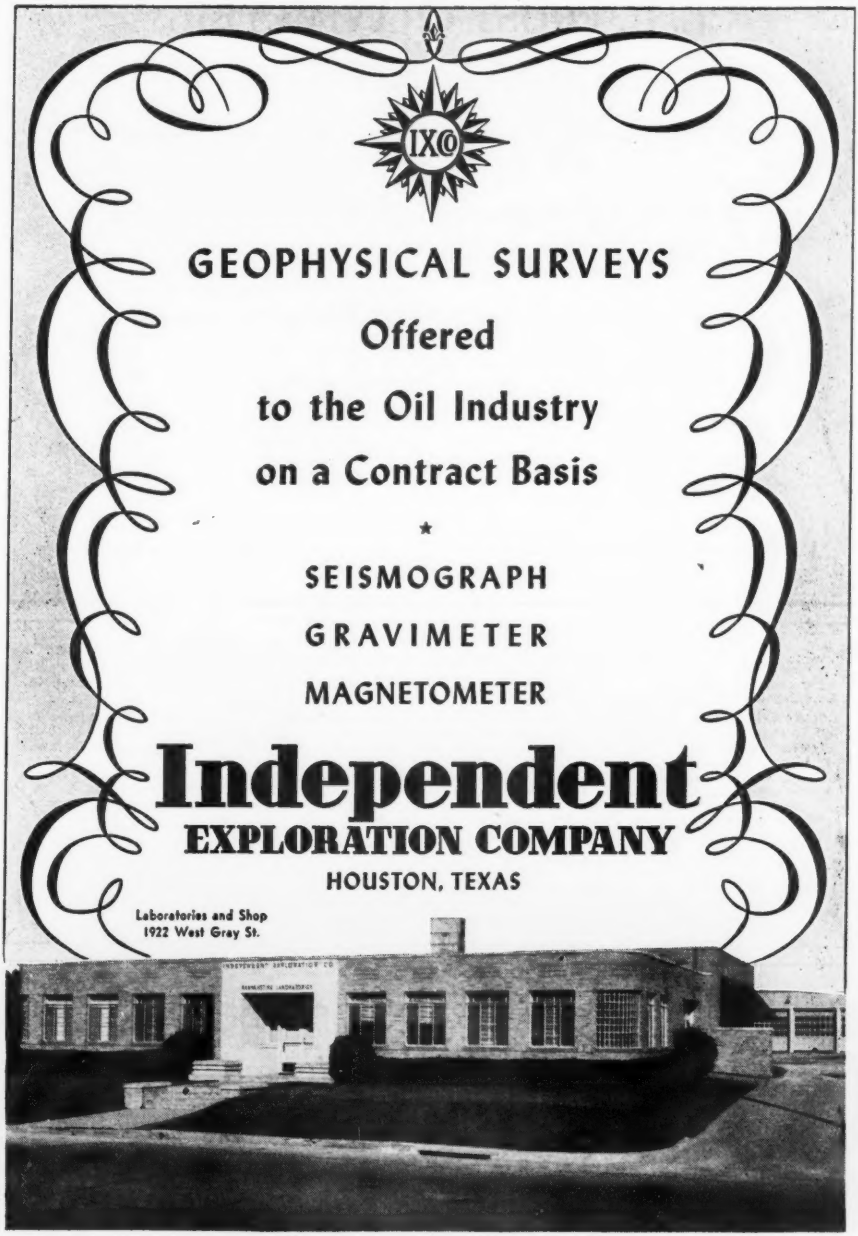
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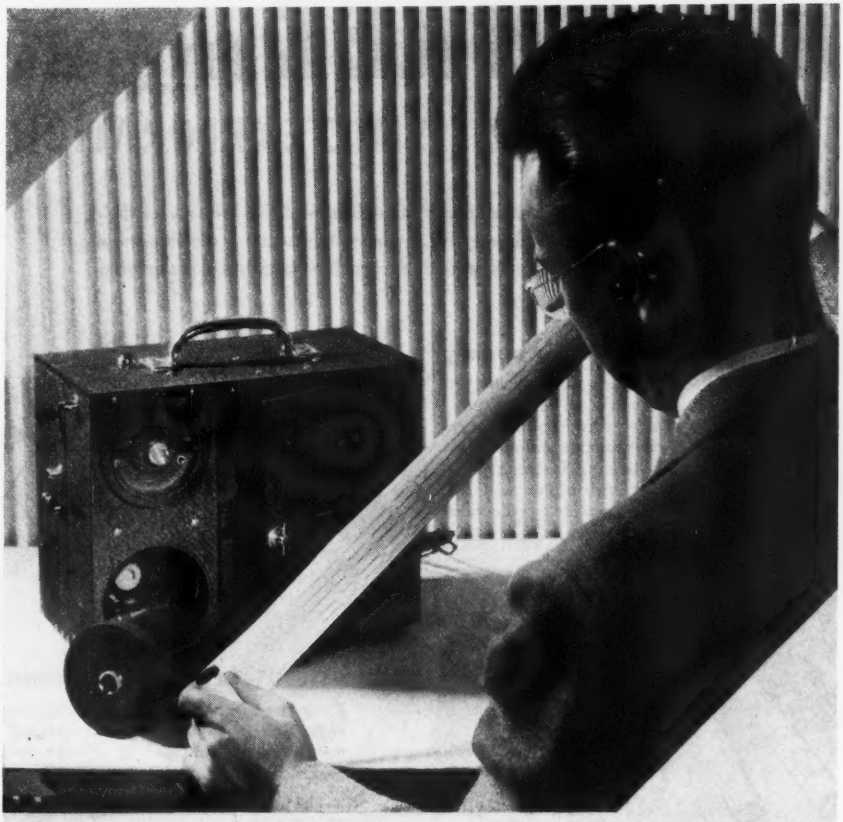
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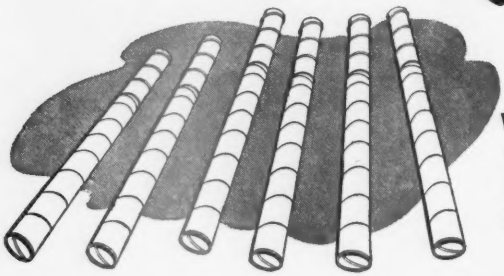


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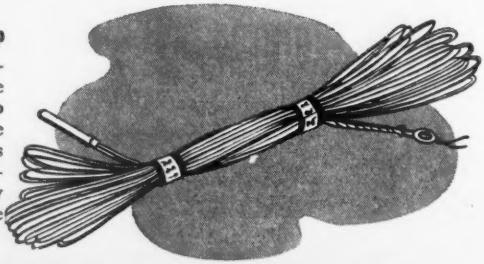


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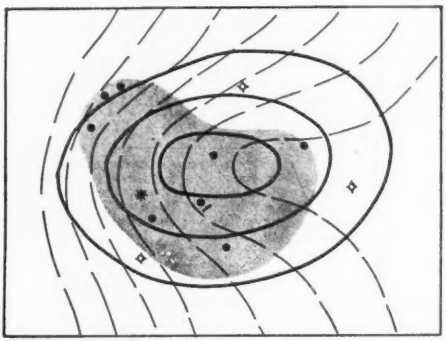
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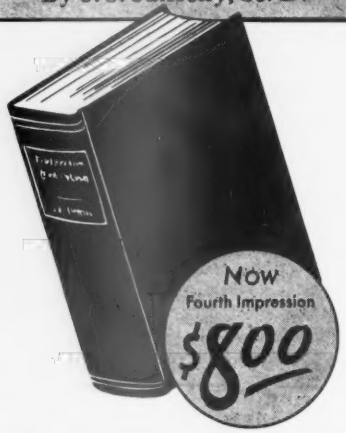
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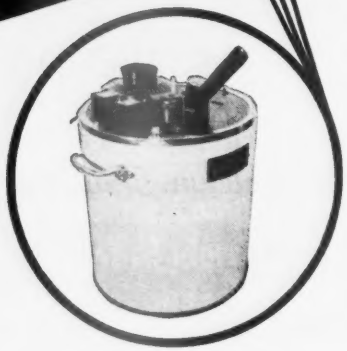
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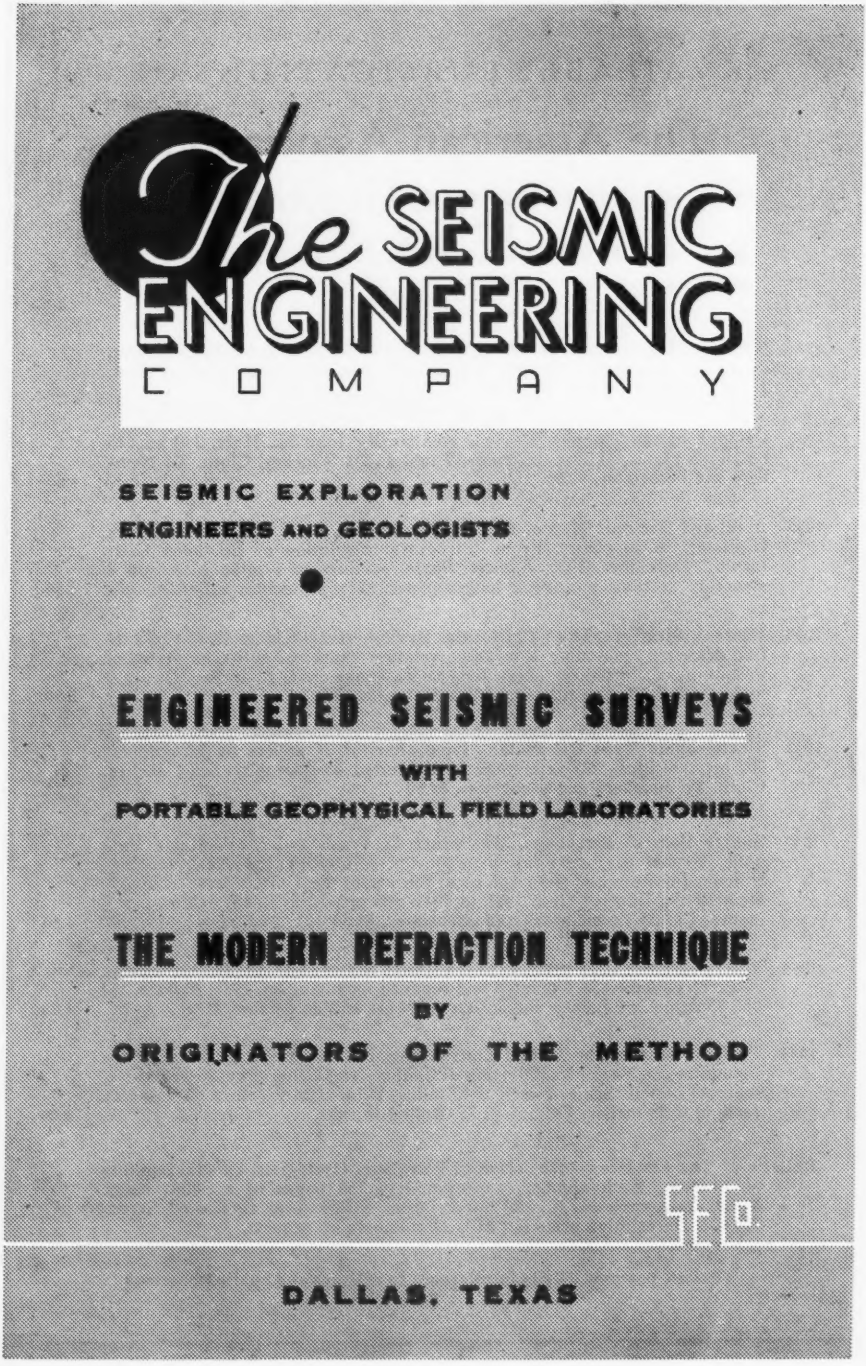
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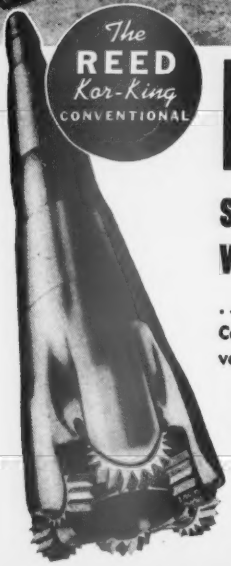
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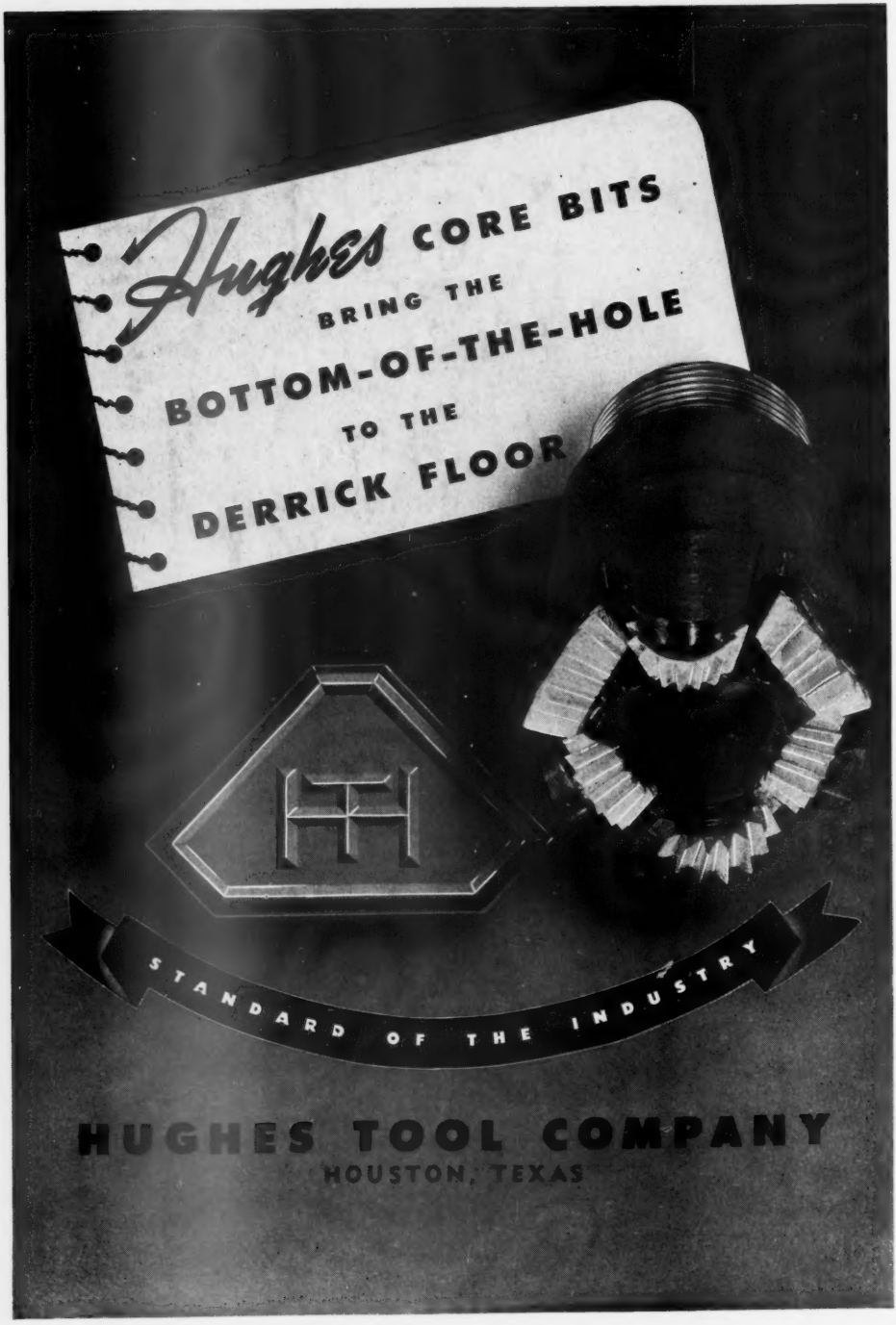


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